Direct Instruction and Metacognition for Mathematical Success for Middle Years and Secondary Students:

Building and Evolving a Foundation of Knowledge and Understanding

by

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Abstract

Learning environment and instructional strategies are key components that build a mathematically successful learning experience. Direct instruction (i.e., traditional instruction) has been argued to provide a better foundation for learning when compared to more alternative methods such as discovery learning. Additionally, when direct instruction is tied to metacognitive strategies, it can increase the potential for learners to be successful. Recently in Alberta, a debate, colloquially referred to as the Math Wars, has focused on whether discovery learning - a learning approach supported by the provincial government - is working. The consensus that has emerged is that no, discovery learning is not working. The trend in Alberta math scores for grades 6 and 12 on provincial assessments has shown a decrease in achievement. It is noteworthy, that math scores in Alberta have dropped coincidently at a similar timing to Alberta's adoption of discovery learning as the main instructional method. The purpose of this project is to review the empirical evidence of the benefits of using a direct instruction approach for teaching mathematics while tying in metacognitive strategies beneficial to helping learners build upon and use their knowledge foundation. This project will be important for any educator because it reviews key literature while at the same time offering suggestions on how teachers can help students achieve mathematical success.

Keywords: Direct instruction, Discovery learning, Metacognitive skills, Math literacy, Mathematical competence, Critical thinking, Middle Year and Secondary Students

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Introduction

This review discusses the benefits of using direct instruction versus discovery learning within the mathematics classroom as well as metacognitive awareness to aid instructional strategies that contribute to mathematical competence. According to the literature, discovery learning, also known as inquiry learning, problem based, experiential, and constructivist learning, is a method of instruction where the student learns how to solve a problem during the process of trying to come up with an answer. It has been around since 1961, periodically disappearing and rising again under a different name (Kirschner, Sweller, & Clark, 2006). Direct instruction (DI), on the other hand, supports a basics first approach, and then an application after the supporting knowledge has been learned. DI explicitly teaches skills and strategies needed to help students be successful by providing them with a strong foundation of knowledge (Bakker, Smit, & Wegerif, 2015).

Metacognition is thinking about one's own thinking and helps learners become aware of what they need to do to solve problems. By increasing learner awareness of what they need to navigate to solve an unfamiliar math question, students can direct their focus to what is needed and from there carry out the proper procedure to be successful (van Velzen, 2016). Student achievement is suggested to increase with explicitly taught metacognitive strategies (du Toit & Kotze, 2009). For the next part of the introduction there will be a discussion of the following: 1) DI versus discovery learning and the effect of using these teaching methods on student mathematical achievement and understanding and 2) metacognition and its impact on the learner. Keeping in line with the goal of student mathematical achievement and the topics mentioned above, within the context of a Middle Years and Secondary Years focus, I will discuss the importance of having a foundation of knowledge from which students can build knowledge and form inferences; past mathematical trends will also be examined.

Personal Interest

I am well into my teaching career and have taught Mathematics, Japanese, and Science, with experience at the secondary and middle school levels. In terms of Mathematics curriculum, I was educated under one curriculum, started teaching another, am presently teaching a third type, and there is a fourth type scheduled to be implemented in the near future. As is reflected in the literature and from what I see as an educator in the teaching profession, there has been a downward pattern observed in mathematical ability in terms of basic skills, as well as a downward pattern in ability and skills at the middle and secondary levels in subsequent years. For example, middle year students have difficulty with basic operations like addition, subtraction, multiplication, and division; in addition to this from my own teaching experience observations, and observations of others such as Stokke (2015), solving for an unknown variable and fraction work have become an area that students really struggle. Fractions have been difficult for students in the past but since the implementation of discovery math fraction comprehension and work with fractions has needed much review and extra work. There is a trickle up effect into secondary, due to lack of ability in multiplying, dividing, and fraction work, factoring of various types has been more difficult for students as well as work with trigonometry, and other areas such as exponents. The areas of trigonometry and factoring have been more difficult for two reasons, 1) lack of basic skills from middles years (Stokke, 2015) and 2) they have been taken out of the discovery learning curriculum altogether for middle year students (Alberta Education, 2007).These factors combined together have coincided with a decrease in math scores for students in Alberta at various levels, as is indicated in the assessment results, particularly on the

Provincial Achievement Tests (PATs) (Alberta, 2016) and Diploma exams (Mark & Mark, 2016).

I had heard about the poor math results here in Alberta (Staples, 2014) from the media and in passing conversations, but have also witnessed them first hand. When the first crop of students from the new discovery learning, came to me in 2010 at grade 10, I noticed a weaker skill set immediately. They no longer had the same “common sense” that the students had from the previous more traditionally taught curriculum. I was finding that I had to reteach quite a few topics such as multiplication and division so that the students could move on to factoring and other multi-step scenarios, or review fraction work altogether. Students typically need extra practice with fractions as mentioned previously, but under the discovery learning method they were completely lost by the time they reached high school, common sense was no longer common.

I was genuinely surprised when discovery learning students said that a number divided by itself was 0 when in fact it should be 1. For example 2/2 = 1 not 0 as some had claimed. In addition to this, when I asked middle school students if they could multiply numbers such as 12 x 12 or 123 x 123 most seemed to have a difficult time, frequently making errors and leading to the incorrect answer. Alternatively, if I wrote 5/3 some had no idea how to put those numbers into the division house ($3\overline{)5}$)and divide correctly. This is a skill that carries directly into dividing polynomials at the secondary level. Students who cannot do division after completing middle school will find math at the secondary level more difficult.

With the presence of discovery learning and students moving onto the next level of math with a narrower skill set than their predecessors, my thoughts moved to what can we as educators do to help them succeed and learn the skills they need to be successful? My thoughts focused on a return to a more traditional approach while at the same time reintroducing concepts at the junior high level that had been taken out during the discovery math's creation such as trigonometry and basic factoring. In addition to this, we as educators should also keep in mind our own knowledge base, the classroom environment, and the metacognitive skills we employ to help our students achieve. I have observed the positive outcome of DI within the learning environment so the purpose of this project is to highlight literature and key points about the positive influence of DI as well as well as supporting instructional strategies in the classroom such as metacognition. My aim here is to provide more of a guide for how to help students learn appropriate strategies at the appropriate times and equip our students with the knowledge base and understanding they need to move out of the classroom.

Background

Since the 1990's, the math wars debate about which method of instruction is the best for mathematical learning has had educators at either end of the spectrum and at odds with each other (Schoenfeld, 2004). Some believe students should be taught with traditional methods while others support more of a learn how to learn approach (i.e., discovery learning). DI and discovery learning come up repeatedly in the research as two of the more prominent methods of mathematical instruction. For the purpose of this paper, these two learning approaches will be discussed as will their effects on student achievement. Evidence suggests that DI in mathematics has a more pronounced and stronger effect on the learner (Adams & Siegfried, 1996; Gersten & Keating, 1987; Kinder & Carnine, 2018; Stokkes, 2015), but proponents of discovery learning support this approach because students will learn more valuable knowledge through constructivism than by having knowledge modelled for them (Loveless, Ladd, & Rouse, 1998; Wu, Tseng, & Hwang, 2015). Supporters of inquiry-based learning also believe students will learn more by discovering something so that they can construct their own concept about the topic and thereby understand it completely (Piaget, 1970). Metacognition is another topic that surfaced during the research and has shown benefits in relation to math achievement (Apaydin, Hossary, 2017; Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014; Farina, Weinberg, & Commitante, 2015; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; Stokke 2015; van Velzen, 2016). Use of metacognitive strategies together with purposeful DI will help the learner have a richer, deeper, and more successful experience (Baten, Praet, & Desoete, 2017; Farina, Weinberg, & Commitante, 2015). The literature has revealed that there is a relationship between positive student achievement and DI as opposed to the use of discovery learning. Also revealed is the fact that metacognition awareness is related to student success (Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014).

Discovery Learning.

Discovery learning, also called experiential learning or inquiry-based learning, seeks to have the learner gain an understanding of their surroundings by experimenting with problem questions to come to some unknown truth by discovering facts, relationships, and underlying causalities for themselves (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010). As mentioned previously, supporters of this teaching style prefer it because they believe it will help students learn valuable knowledge (Loveless et al., 1998; Wu, Tseng, & Hwang, 2015) by trying to work out a problem by themselves with little or no guidance. However, studies done on classrooms that use discovery learning point to the fact that if it is the sole method of instruction students can expect to experience cognitive overload and a decrease in achievement (Kirschner et al., 2006).

Discovery learning has been around for half a century and research done on this technique almost uniformly supports DI instead because discovery learning is less effective and causes negative side effects such as students coming to wrong conclusions without direct guidance (Kirschner et al., 2006; Mayer, 2004). In addition to this Kirschner, Sweller, and Clark (2006) noted that discovery learning has been around since 1961, periodically disappearing and rising again under a different name, with the new set of advocates unaware that the unguided form of instruction had not been validated.

Direct Instruction.

DI uses explicit instruction to ensure that students get the guidance they need to proceed from developing base knowledge, to addressing problems, to completing them successfully. By doing this, DI lays out a clear process of skill introduction, modeling the skill, guided practice, independent practice, assessment, and review (Crane, & Brannen, 2008) to determine if all concepts have been grasped and correct lines of work are proceeding. According to the research DI has been around for quite some time and its benefits in terms of student achievement or IQ, compared to other instructional methods such as discovery learning, is well documented (Kinder, Ph, Carnine, & Ph, 2018). Lai and Murray (2012), and Yeo (2009) have found that rote learning using a DI approach encourages deeper understanding of higher-level math concepts, and creates a strong foundation of algorithmic, linguistic, conceptual, and strategic knowledge which are all vital components in problem solving. Lai and Murray (2012) have found that the "learners recognise the mechanism of repetition as an important part of the process of memorization and that understanding can be developed through memorisation" (p. 4). Lai and Murray (2012) also note that "repetition can create a deep impression on the mind and enhance memorisation" and that "repetition can be used to deepen and develop understanding" (p. 4).

Metacognition in Education.

Another topic that kept surfacing during the literature review was metacognition. Metacognition is thinking about one's own thinking. Metacognition aids in math learning and improves learning quality (Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014) using various techniques such as self-monitoring - the ability to say what they don't know by unpacking a question, self-error correcting after base knowledge has been taught, paraphrasing, and prompt and guide-again after they have been given a base of knowledge to draw upon (du Toit & Kotze, 2009; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; van Velzen, 2016). Using these and other strategies, to be discussed later, learners will efficiently turn intrinsic thought into procedural application because they have been explicitly instructed how to think through problems. The learner is now able to practice and apply what they have been taught to related and unrelated questions and problems, while still making use of strategic guidance, enabling them to self-correct more efficiently through reflection (Heemsoth & Heinze, 2016).

Research Questions

Three main areas that I would like to explore that stood out to me during the process of reviewing the mathematical literature are:

1. What support can be found in the research for using Inquiry Learning for the mathematics classroom?
2. How does DI promote achievement in the middle and secondary school classroom?
3. How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?

Definitions

To help make sense of strategies to help middle year and secondary students succeed mathematically, knowledge of certain vocabulary will be beneficial; vocabulary such as *DI, discovery learning, metacognitive skills, math literacy, mathematical competence, critical thinking, and middle year and secondary.*

Direct instruction, also known as traditional instruction, is defined as "providing information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture" (Kirschner et al., 2006). DI is the use of straightforward, explicit teaching techniques, usually to teach a specific skill. It is a teacher-directed method, meaning that the teacher stands in front of a classroom and presents the information in various presentation methods.

In regards to *Discovery learning* it is said that learners learn how to learn to discover facts and truths to be learned and used, over an extended period of time. The idea is that "discovery learning occurs whenever the learner is not provided with the target information or conceptual understanding and must find it independently and with only the provided materials" (Alfiere, Brooks, Aldrich, & Tenenbaum, p.5, 2010). However, despite an in-depth analysis, Duffy and Tobias (2009) were unable to definitively say that there is any evidence supporting the use of discovery learning also known as implicit learning.

Use of metacognition, thinking about one's own thinking, to develop m*etacognitive skills* will help students think about their own thought processes and raise their own awareness of what they are thinking at times of problem solving and other life scenarios. It is also known that children with well-understood metacognitive knowledge performed better on problem-solving tasks (Y. Lai, Zhu, Chen, & Li, 2015).

Numeracy is the ability to reason critically about quantitative data (Gittens, 2015) and will help students be successful in and out of the classroom environment. Numeracy is also “the confidence and habits of mind to engage with, critically assess, reflect upon and apply quantitative and spatial information when making judgements and decisions or taking actions in all aspects of daily living” (Edmonton Catholic, 2015, p. 2).

Mathematical literacy is the idea that not only do students know the language and vocabulary of math but also have the ability to analyze, reason, apply, and solve problems in familiar and unfamiliar contexts. By being mathematically literate students are successful in and out of the classroom environment.

Mathematical competence is achieved when students are math literate and have mastery knowledge of numeracy and are therefore able to think critically about and analyze problems in daily life. This is a main goal of any mathematics educator that hopes to see their students succeed.

Critical thinking is tantamount when approaching unfamiliar contexts mathematically. *Critical thinking* is the objective analysis and evaluation of a situation to come to a conclusion about a scenario observed or experienced. By thinking critically about a problem through self-reflection learners are better able to think about what they are thinking and how they know what they know. Heemsoth and Heinze (2016) would agree with this as they concluded, using error-centered strategy to correct their own errors after prerequisite knowledge had been taught, that students improved their overall mathematical achievement by critically thinking about how best to correct mistakes made. This is also a strategy of metacognition to improve their mathematical skills by having students identify what they did not previously know or understand.

Middle year and secondary level students are defined as middle year, also known as junior high, students in grades seven to nine and between ages of twelve to fifteen and secondary level, also known as high school, students in grades ten to twelve and between ages of fifteen to eighteen.

Research Pathway

My original thought was to investigate DI and compare it to discovery learning since I teach math and have seen the trends first hand of math scores slumping over the last few years in Alberta and Canada. However, the more I thought about it and the more research I read I began to think that the reason I was going to compare the two was so that future students would benefit from present day practices and to me the present day of discovery learning is not doing justice to students. I began to realize also that to help students and other interested parties I could research more than just a comparison of the two methodologies. As I broadened my search, things like metacognition strategies aimed at helping students become mathematically competent and math literate, warranted some discussion.

To that end I used search terms like mathematical competency, mathematical literacy, traditional methods vs. discovery methods, traditional math, discovery math, Project based learning, math learning strategies, math learning strategies and traditional instruction, as well as metacognitive strategies for math. There were many resources to sift through but making sure they were from five to ten years previous, peer reviewed and scholarly, had a methods section to ensure they were empirical, and journals or journals and books, definitely helped narrow down the search. I mainly used the University of Victoria library search engine but also used google scholar and examined mathematical journals and archives such as Mathematics Education Trends and Research, The International Journal on Mathematics Education, The Journal of

Experimental Education, Center for Educational Policy Studies Journal, Educational Psychologist, and International Journal for Mathematics Teaching & Learning to name a few.

When researching for discovery versus DI I read articles that were about discovery to see if it had support from educators or researchers, and generally the trend was to support direct teaching. I also discovered a book that scrutinized one of the main articles that I used to support direct teaching instead of discovery and decided to cite it because it’s a good idea to come at a topic from multiple angles. The authors, Duffy and Tobias (2009), did however; conclude that due to the paucity of supporting research for discovery learning, they could not note conclusively that there is any benefit of using discovery learning. In this review there will be a discussion about the benefits of DI and some supporting strategies as well as metacognition and its supporting strategies leading to effective education.

Literature Review

The goal of this literature review is to discuss what will help students be successful in the mathematics classroom. The review discusses why some might prefer Discovery Learning (Bruner 1961; Loveless, Ladd, & Rouse, 1998; Piaget, 1970; Wu, Tseng, & Hwang, 2015), while at the same time providing evidence for Discovery Learnings' lack of support for promoting effective learning (Alberta, 2016; Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Csanady, 2016; Duffy & Tobias, 2009; Kirschner et al., 2006; Mark & Mark, 2016; Paas, Renkl, & Sweller, 2003, 2004; Staples, 2014; Sweller, 1988). The review also suggests that DI is beneficial to student achievement (Adams & Siegfried, 1996; Bakker, Smit, & Wegerif, 2015; Crane, & Brannen, 2008; Kinder, Ph, Carnine, & Ph, 2018; Lai & Murray, 2102; Mayer, 2004; Yeo, 2009; Stokke, 2015). The review also discusses metacognition, its association with DI, and its positive effect in the classroom and on mathematical achievement (Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014; Doll, 1993; du Toit & Kotze, 2009; ; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; Kingsdorf & Krawec, 2016; van Velzen, 2016; Y. Lai, Zhu, Chen, & Li, 2015). By examining the research three questions are answered in the literature review: What support can be found in the research for using Inquiry Learning for the mathematics classroom? How does DI promote achievement in the middle and secondary school classroom? How can metacognitive strategies be combined with DI to improve student outcomes in mathematics? The three questions will be answered in separate sections using empirical studies to verify the validity of statements made in this review.

In regards to the first question, What support can be found in the research for using Inquiry Learning for the mathematics classroom?, the findings suggest that despite some educators preferring discovery learning (Bruner, 1961; Loveless, Ladd, & Rouse, 1998; Piaget, 1970, Wu, Tseng, & Hwang, 2015) it is not effective as the sole method of instruction, especially when only pure discovery methods are used as the instructional technique (Alberta, 2016; Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Csanady, 2016; Duffy & Tobias, 2009; Kirschner et al., 2006; Mark & Mark, 2016; Paas, Renkl, & Sweller, 2003, 2004; Staples, 2014; Sweller, 1988;). Sub-themes that surfaced during the literature review about inquiry learning revolved around how it is ineffective due to cognitive load (Kirschner et al., 2006), evidence indicates that use of inquiry learning has its drawbacks and needs to be combined with some form of guided education to help the learner succeed (Duffy & Tobias, 2009; Kirschner et al., 2006), and mathematics scores in Alberta decreased coinciding with the timing of discovery maths' inception (Alberta, 2016; Mark & Mark, 2016; Stokke, 2015). In the review, each of these sub-themes empirically point out that discovery learning alone does not support effective learning. The learner can use inquiry to learn but it should not be the sole method of instruction (Bruner, 1961; De Bruyckere, Kirschner, & Hulshof, 2015; Dewey 1910; Littleton, Scanlon, & Sharples, 2012) so a better approach is to use additional techniques such as metacognition strategies and DI. After these themes have been reviewed there will be a discussion section.

The research for the second question, How does DI promote achievement in the middle and secondary school classroom?, stated that having explicit structured instruction led to better student achievement (Adams & Siegfried, 1996; Bakker, Smit, & Wegerif, 2015; Crane, & Brannen, 2008; Kinder, Ph, Carnine, & Ph, 2018; Lai & Murray, 2102; Mayer, 2004; Novosel, 2018; Stokke, 2015; Yeo, 2009). Sub-themes that emerged from the literature that help the learner be successful mathematically, and are the basis for DI, are deeper learning by DI and structured learning including topics such as worked examples, and scaffolding (Bakker, Smit, & Wegerif, 2015; Clark, Nguyen, & Sweller, 2006; Crane, Brannen, 2008; Novosel, 2018; Ward &

Sweller, 1990; Stokke 2015). These sub-themes will be examined in relation to how DI promotes mathematical achievement and will be followed by a discussion section.

In the third section the question, How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?, will be answered. According to the research, explicitly instructed metacognitive strategies positively affect student mathematics learning quality and achievement (Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014; Doll, 1993; du Toit & Kotze, 2009; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; Kingsdorf & Krawec, 2016; van Velzen, 2016; Y. Lai, Zhu, Chen, & Li, 2015). DI along with metacognitive strategy training has been linked to improving student achievement by means of four sub-themes that arose from the research such as self-questioning and reflection (Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016), critical thinking (Doll, 1993), feedback (Farina, Weinberg, & Commitante, 2015), and mathematical literacy and numeracy (Edmonton Catholic, 2015; Gittens, 2015; Government of Alberta, 2013). In this section of the review, these sub-themes will be examined for their effect on mathematical performance and competence.

From the material reviewed in the literature, the findings suggest that DI is the better choice for educators when contemplating instructional styles as it leads to less cognitive dissonance and stronger mathematical competence and achievement. Metacognition also has support as a valid strategy to promote positive results in terms of student mathematical achievement. Considering these topics and using the reviewed literature, I will answer the following three questions: (a) What support can be found in the research for using Inquiry Learning for the mathematics classroom? (b) How does DI promote achievement in the middle and secondary school classroom? (c) How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?

Inquiry Learning in the Classroom

Introduction. The first section of the review will be examining the research question, What support can be found in the research for using Inquiry Learning for the mathematics classroom? The purpose of positing this question is to determine what the research is saying about inquiry learning. According to the literature, discovery learning, a form of inquiry learning, has some followers stating that it allows learners to be free and take control of their learning experience (Bruner, 1961; Chu, Reynolds, Tavares, Notari, & Lee, 2017; Dewey, 1910; Loveless, Ladd, & Rouse, 1998; Piaget, 1970; Wu, Tseng, & Hwang, 2015). Discovery based learning supporters claim that through the process of discovering something about their environment, learners will uncover truths that cannot be understood by lecture alone (Bruner, 1961; Chu, Reynolds, Tavares, Notari, & Lee, 2017; Dewey, 1910; Loveless, Ladd, & Rouse, 1998; Piaget, 1970; Wu, Tseng, & Hwang, 2015).

Bruner (1961) is considered to be the father of constructivist learning and it was his belief that spawned the discovery type of thinking when learning new concepts, which exists today. Dewey (1910), also a proponent of learn by doing, focused on the individual commenting that it is important to allow learners to gain insight into their surroundings by interacting with their environment. These are valid thought provoking strategies, however, Dewey believed that natural intelligence, thinking, is what can lead learners to make their own conclusions and therefore possibly come to false or wrong conclusions (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Dewey 1910). Dewey (1910) stated that to avoid negative outcomes, students should be trained how to think and given the necessary background to deal with new scenarios. Bruner (1961) also warned that discovery learning styles should not be the main focus, noting that some base knowledge should be taught before the learner is set off on their own as their mind needs to be prepared for discovery.

Supporters of inquiry learning believe it allows learners to have the opportunity to construct meaning out of their environment, and thereby encourages learners to create their own learning experiences. However, the opposing research data discusses reasons why inquiry learning is an ineffective instructional method (Alberta, 2016; Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Csanady, 2016; Duffy & Tobias, 2009; Kirschner et al., 2006; Mark & Mark, 2016; Paas, Renkl, & Sweller, 2003, 2004; Staples, 2014; Sweller, 1988). Through the process of examining the research three sub-themes have emerged that will now be reviewed: lack of evidence for discovery learning, cognitive load, and decreasing math scores in Alberta.

Lack of evidence for discovery learning. The main challenge of discovery learning that arose from the literature is that there is concern that it is an ineffective instructional strategy leading to negative outcomes (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Duffy & Tobias, 2009; Kirschner et al., 2006; Paas, Renkl, & Sweller, 2003, 2004 Sweller, 1988). For example, Kirschner et al. (2006) stated in their conclusions that use of less guided instruction such as inquiry learning is less effective and evidence suggests “that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge” (p. 84). As pointed out earlier, even an inquiry learner supporter like Dewey (1910) says that there needs to be guided instruction first to set the learner on the correct path and avoid forming incorrect conclusions. Kirschner also reviewed meta-analysis data on a variety of sources such as quantitative, qualitative, and theoretcial studies such as dissertations and articles and concluded that the data does not support the use of inquiry instruction.

Kirschner cautioned against thinking that pedagogic content is similar to and replaceable by the methods and process that go along with inquiry; knowledge learned is valuable and should not be replaced with a focus on how to solve a problem without having the tools or prior knowledge. The process of building a knowledge base from which to draw upon for future problem solving scenarios requires the intentional aquiring of strategies to adapt to and solve problems; experts did not become experts overnight, they accummulated experience to grow knowledge slowly, and this cannot be replaced with inquiry learning (Dehoney, 1995; Kim & Axelrod, 2005). Kirschner points out a couple other pieces of research (Handelsman et al., 2004; Hodson, 1988) that add to this by noting that by using more of a constructivist method there is a shift away from teaching as a discipline with a focus on knowledge to one with a focus on process and procedure. When inquiry is used instead, it gets the learner to try to learn by doing but the process is not explained or discussed so the why or how something works is not truely learned; additionally in some cases the students actually knew less after being instructed with discovery learning than prior to the lesson (Kirschner et al., 2006). This happens when learners do not get the guidance they need and form their own erroneous conclusions from misconceptions picked up during the process of discovery.

Findings about discovery generally stated there is not enough supporting literature to consider using it as the sole method of instruction (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Duffy & Tobias, 2009; Kirschner et al., 2006). In fact, some go as far as to say that there is a growing body of evidence indicating that students gain a deeper understanding using DI versus discovery learning (Moreno, 2004). Kirschner et al. (2006) would agree and add that from the available studies, the literature almost uniformly supports the strong direct guidance of DI versus constructivist discovery learning. Also noted was that even if students have a strong foudation of knowledge to build on they still need strong guidance to succeed.

Further research into the effectiveness of inquiry learning, objectively, methodically, and empircally analyzed inquiry learning to see if it was an effective form of instruction. Duffy and Tobias (2009) thouroughly analyzed Kirschner et al.'s (2006) research to see if they could come up with constradicing data in support of discovery learning, but after an exhausting analysis of the pros and cons they were unable to conclusively say that there was clear evidence supporting the use of inquiry learning or its' effectiveness as the main instructional method. Novosel (2018) has indicated that since discovery learning has been implemented, students taught with inquiry methods are unprepared for mathematics at the middle years and secondary levels.

More specifically, Novosel (2018) comments that mathematical competence has decreased along with the rigor needed to be successful, leaving students unprepared for future math classes. Novosel goes further by saying that many students now struggle with basic skills like, multiplying, adding, subtracting, dividing, fraction work, percentage work, order of operations also known as BEDMAS (brackets, exponents, division, multiplication, addition, subtraction), decimals (all operations & rounding), exponent work, surface area, solving equations, and solving equations with fractions. According to him it is clear that educators are not preparing students for the future while using inquiry tactics because students are now unable to handle the rigor expected of them in high school, unable to keep up with the amount of material due to lack of basic skills, have poor work habits, and are less disciplined when it comes to doing what they need to be successful mathematically.

Cognitive load. Cognitive load is defined as "the amount of capacity the performance of a cognitive task occupies in an inherently capacity-limited system" (Chen, 2017, p. 4), in short, the effort used in working memory. In relation to cognitive load and structure, Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) studied two types of problem solvers to answer the question “Why should some forms of problem-solving search such as means-ends analysis interfere with learning?” (Sweller, 1988, p. 5). He defines one type of problem solver as a means-end type, inquiry learning, where more novice skills are put to use in a working backwards process versus experts who possess schemas allowing them to efficiently organize data from questions into a manageable form to be ordered and then proceed from beginning to final answer.

Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) state it is the schema, a cognitive structure that enables problem solvers to recognize particular moves needed, that allows the learner to be efficient. It is this efficiency that frees up cognitive space allowing for true learning to happen. In their studies it is stated that having more structured cognitive architecture with pre-learned procedure, schemas, will aid in decreasing cognitive load. Sweller (1988) backed up the statements in his study on problem solving involving trigonometry with triangles. In his study there were 24 students, year 10 high school, split into 2 groups of 12, a conventional and non-specific goal group. The conventional group was responsible for giving the proper steps needed to solve for particular sides of a triangle using the trigonometry functions in the proper order with the proper measurements, for 6 problems. They were told to solve for the unknowns but the actual focus was on whether they could successfully set up the trigonometric ratios so that the problem could be solved. Similar problems were used for the non-specific group except that they were told to solve for as many sides as possible with the exception of a couple that had been crossed off; again they were told to solve 6 problems but the focus was on getting the correct equations to solve. Both groups were also told that after solving the problems, the questions would disappear and the subjects would need to reproduce the previous question after solving it before moving onto the next problem. Sweller (1988) noted that each group got faster with each subsequent problem and produced less error but the non-specific group was able to solve the problems consistently faster than the conventional group. Overall Sweller (1988) concluded that the increased cognitive load, needed by the conventional group, interfered with task performance from one task to the next. Alternatively, he noted that there is still capacity available after solving a non-specific problem than a conventional problem, Sweller (1988) says this decreased cognitive load is what enabled the non-specific group to have superior performance in all aspects of the experiment such as performance on angle-position, side-position, and solving ability.

In a follow-up study by Sweller, Ayres, and Kalyuga (2011), the importance of schemas, in Swellers (1988) study, was reaffirmed as a crucial element to learner success, allowing the learner to experience decreased cognitive load, freeing up their working memory, and enabling them to be more efficient problem solvers that make fewer errors. Sweller, Ayres, and Kalyuga (2011) added to this by noting that the learner experiences more success using a goal-free strategy versus the previously mentioned means-end method. By making use of goal-free strategies, and associated schemas, the learner analyzes a problem holistically to find all unknowns about a problem versus following a strict set of rules (Sweller, Ayres, & Kalyuga, 2011). Using goal-free strategies allows the learner to move more smoothly from one step to the next decreasing cognitive load contributing to “significantly improved learning outcomes including transfer” (Sweller, Ayres, & Kalyuga, p. 98, 2011) of knowledge to other unfamiliar scenarios.

It is the goal of education to perpetuate and advance culture, perform appropriately by making use of long term memory, and to help the student learn and to incorporate new schemas

(Sweller, Ayres, & Kalyuga, 2011). Kirschner et al. (2006) suggested that students being taught with minimal guidance are being overwhelmed because they were not taught foundational skills and lack the schemas needed to solve problems but are now being expected to use their working memory to solve problems when their working memory is already taxed trying to figure out new strategies or create new skills to deal with unfamiliar questions. According to Kirschner et al. (2006) long term memory's role had taken a back seat but is now gaining traction as an important component of problem solving. Having knowledge in long term memory is important because it allows the learner to quickly recall the needed information or skill for a particular problem and get back to solving the problem. If knowledge is not available in long term memory then it becomes the job of working memory to find the appropriate data or skill needed to problem solve (Kirschner et al., 2006). This leaves the student cognitively unable to learn new material because working memory is needed, increasing cognitive load, for learning but it is too busy trying to fill in gaps left by constructivist instruction (Kirschner et al., 2006; Paas, Renkl, & Sweller, 2003, 2004).

If a student's long term memory possessed the needed knowledge, that would have been learned prior to a problem solving scenario, the limits of working memory and cognitive load become less of an issue (Kirschner et al., 2006). However, with what Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) said about the processing power needed to approach unfamiliar questions or scenarios after the whole process of trying to figure out which strategy to use, which skills must be learned and in what order they should be used, and finally to carry out some sort of procedure to come up with an answer there will not be a lot of processing capacity left for true learning if the learner does not lessen the burden of a heavy cognitive load.

Mathematic Scores in Alberta. In recent years, use of discovery learning, also known as inquiry or experiential learning, has coincided with a decrease in math competency and performance (Csanady, 2016). Program of International Student Assessment (PISA) assessed mathematics as a major domain in 2003 to assess student ability and compared these results from the baseline year of 2003 to the most recent year of testing, 2012. PISA scores have been steadily decreasing for about a decade (see figure 1) which is similar in timing to when discovery learning was implemented as the main mathematics instructional method in Alberta. According to the results Alberta math scores decreased 32 points between 2003-2012 (OECD, 2014). To put that in perspective in terms of schooling, 41 points corresponds to the equivalent of one full year of education so a decrease of 32 points clearly indicates that there has been a significant decrease in math literacy and ability. This is evident when comparing levels of ability by looking at PISA scores. The levels of ability for PISA range from 1 being the lowest, very poor math ability, to 6, very competent at solving complex problems (OECD, 2014; Stokke, 2015). The results of the last PISA indicated that students in Alberta at level 2 doubled while those at level five halved.

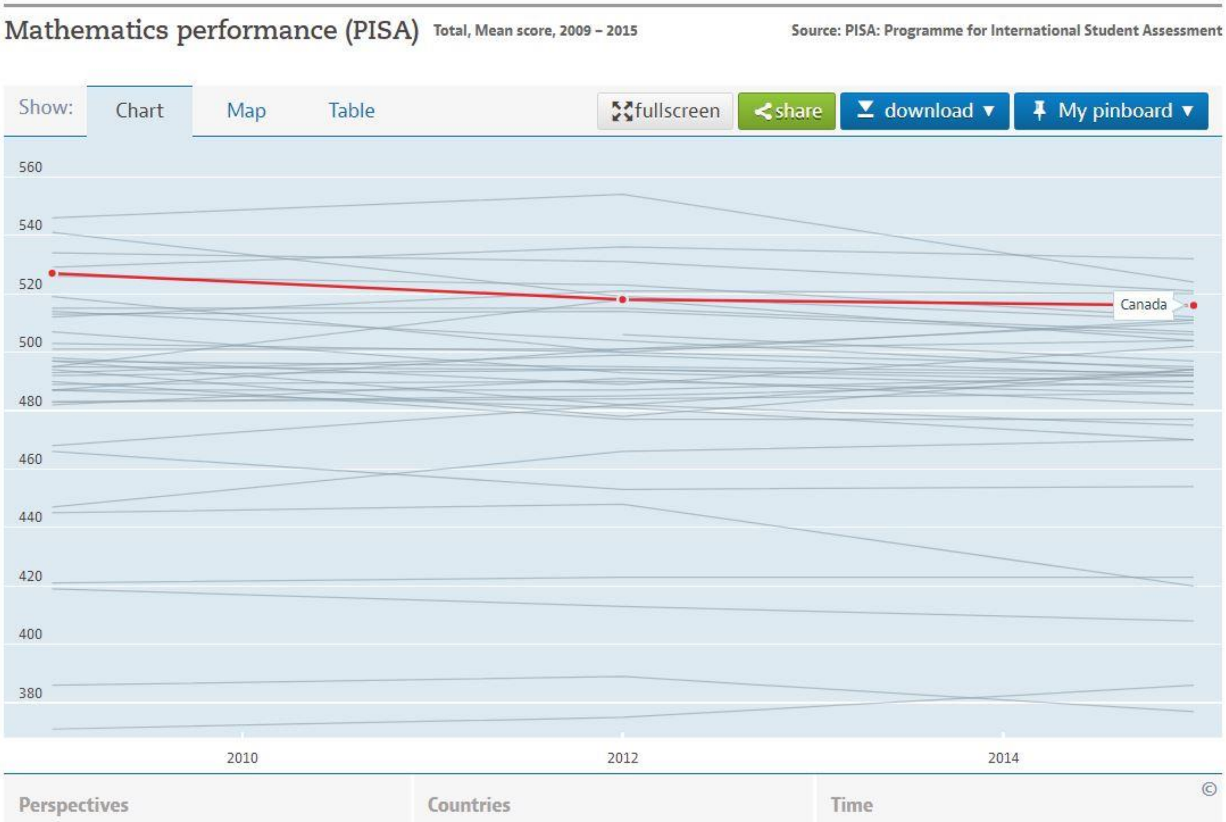


Figure 1. PISA scores in Canada

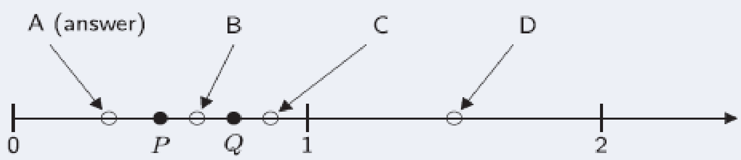
Trends in International Mathematics and Science Study (TIMSS) confirmed that students in Alberta have experienced a decrease in ability (Mullis, Martin, Pierre, & Arora, 2012). TIMSS assesses specific math skills such as fractions or algebra and has recently discovered that students from Alberta have decreased 26 points indicating a significant decrease in mathematical ability. For example, Alberta students now rank near the bottom in regards to performance with fractions, specifically basic skills needed to work with them or multiply them, as can be seen in figure 2.

Figure 1: Two Grade 8 TIMSS Questions (2011)

I. (Basic arithmetic with fractions) Which method will find $\frac{1}{3} - \frac{1}{4}$?

$A: \frac{1-1}{4-3}$ $B: \frac{1}{4-3}$ $C: \frac{3-4}{3 \times 4}$ $D: \frac{4-3}{3 \times 4}$ (answer)

II. (Understanding multiplication) Fractions P and Q are shown on a number line. Which is the correct location of $N = P \times Q$?



Source: Adapted by Robert Craigen from Mullis et al. (2012).

Success Rates

System	I. Fractions	II. Multiplication
KOREA	86	44
SINGAPORE	83	45
TAIPEI	82	53
HONG KONG	77	47
QUEBEC	33	29
ONTARIO	33	27
ALBERTA	28	24
WORLD	37	23
GUESSING	25	25

Source: Compiled by Robert Craigen from Mullis et al. (2012).

Figure 2. Two Grade 8 TIMSS Questions (2011)

Alberta math scores on Provincial Achievement Tests (PAT's) have shown a decrease in mathematical achievement for the years 2012-2016 (Alberta, 2016). For example, there has been a decrease in the number of students at the standard of excellence and acceptable levels while there has been an increase in the number of students below acceptable standards (See figure 3).

Provincial Achievement Test Multiyear Reports

Alberta Government

Province: Alberta

Mathematics 6 - All Students Writing

	2011/2012		2012/2013		2013/2014		2014/2015		2015/2016*	
	N	%	N	%	N	%	N	%	N	%
Participation										
Enrolled [a]	43211	100.0	44117	100.0	45709	100.0	47496	100.0	47512	100.0
Writing	39308	91.0	40104	90.9	41435	90.6	43103	90.8	43210	90.9
Absent [b]	1919	4.4	1573	3.6	2008	4.4	2105	4.4	2001	4.2
Excused	1984	4.6	2440	5.5	2266	5.0	2288	4.8	2301	4.8
Results Based on Number Enrolled										
Total Test										
Standard of Acceptable	32298	74.7	32221	73.0	33576	73.5	34788	73.2	34281	72.2
Standard of Excellence	7184	16.6	7250	16.4	7031	15.4	6685	14.1	6650	14.0
Below Acceptable Standard	7010	16.2	7883	17.9	7859	17.2	8315	17.5	8929	18.8
Results Not Available [c]	3903	9.0	4013	9.1	4274	9.4	4393	9.2	4302	9.1
Results Based on Number Writing										
Total Test										
Acceptable Standard	32298	82.2	32221	80.3	33576	81.0	34788	80.7	34281	79.3
Standard of Excellence	7184	18.3	7250	18.1	7031	17.0	6685	15.5	6650	15.4
Below Acceptable Standard	7010	17.8	7883	19.7	7859	19.0	8315	19.3	8929	20.7
Mean (%)	39308	61.2	40104	56.4	41435	57.1	43103	60.8	43210	64.1
Standard Deviation	39308	19.8	40104	20.0	41435	20.3	43103	20.2	43210	20.8

a Includes all students registered in Grade 6 and ungraded students in year 6 of schooling. School Authority results do not include students in home education programs.
b Includes students who were absent for the entire test or part of the test, and those who wrote but whose results were withheld.
c Includes students who were absent, excused by the superintendent, or who wrote but whose results were withheld. It is possible that some students, under different circumstances, could have demonstrated standards on the test.
* The 2015/2016 results do not include students who were exempted from writing the test because of the Fort McMurray wildfires.
Please read "Guidelines for Interpreting the Achievement Test Multiyear Reports."

Report Generated: Dec 03, 2016
Current data with count less than 6 suppressed for Oct 2016

Report Version 1.0
Data Current as of Nov 02, 2016

Figure 3. Provincial Achievement Tests

There are similar and more pronounced findings for the diploma level government exams at the secondary level (grade 12) (Mark & Mark, 2016), showing a 10% decrease in both the standard of excellence and acceptable standard from 2011-2016 (see figure 4). Middle year (grade 9) students have also failed to meet provincial government targets prompting Albertan's to set new goals for improved numeracy for grades K-12.

Diploma Examination Multiyear Reports

Alberta Government

Five-Year Diploma Examination Results

Province: Alberta

Mathematics 30-1

	2011/2012	2012/2013*	2013/2014	2014/2015	2015/2016**
Number of Students	n/a	19,897	21,358	20,951	20,492
School-Awarded Mark					
Standard of Excellence (%)	n/a	44.2	46.1	49.0	50.7
Acceptable Standard (%)	n/a	95.9	95.6	95.9	96.4
Average (%)	n/a	74.9	75.5	76.3	77.0
Standard Deviation (%)	n/a	14.3	14.4	14.4	14.4
Diploma Examination Mark					
Standard of Excellence (%)	n/a	35.9	27.9	31.6	25.9
Acceptable Standard (%)	n/a	80.9	75.1	76.1	70.7
Average (%)	n/a	69.1	64.2	65.6	62.2
Standard Deviation (%)	n/a	20.3	20.4	21.1	21.2

* The 2012/2013 results do not include students who were exempted from writing the examination because of the flooding in Calgary and southern Alberta.

** The 2015/2016 results do not include students who were exempted from writing the exam because of the Fort McMurray wildfires.

Figure 4. Diploma Exam Results

Staples (2014) has argued that these results and others like it are correlated directly with the inception of inquiry learning in Alberta. In a 32-part article about math in Alberta, Staples (2014) says that discovery learning is getting a failing grade due to reports from secondary teachers and their frustrations with inquiry learning, the difficulties students experience due to missing basic skills, and from post-secondary educators about the need for back to basics, and more of a traditional approach to teaching mathematics. Staples (2014) points out a couple reasons for Alberta's poor mathematical performance lately is that students are being made to learn multiple convoluted methods of doing one task instead of one straight forward method. He also mentions that the curriculum has been watered down in comparison to other countries like Singapore and Finland stating that those students can work with fractions by the end of grade 5 or 6 versus grade 7 here in Alberta. From his research into Alberta's education system and in discussions with educators there is a call for a return to basics.

Discussion. From the literature reviewed, the research question, What support can be found in the research for using Inquiry Learning for the mathematics classroom?, has been explored. Inquiry or discovery methods have shown to cause cognitive overload in students leading to erroneous conclusions if left unguided, indicating that strong guidance is necessary for effective learning. There is not enough evidence to support the use of discovery learning in general. To be a useful method of instruction, the method should have positive effects on the learner but through the review of the research this is not the case. An examination of the empirical literature has indicated the opposite to be true, stating discovery learning is not recommended (Duffy & Tobias, 2009; Kirschner et al., 2006). Supporters of inquiry or discovery learning even point out if it is to be used there needs to be some form of direct guidance and some direct teaching of rudimentary foundational skills to process higher order problem solving for complex problems (Bruner 1961; Dewey 1910). Inquiry learning has been used in Alberta recently and has coincided with a drop in mathematical achievement for middle years and secondary level students.

In conclusion, the literature has revealed that the arguments for using Inquiry learning in the mathematics classroom do not recommend it due to cognitive overload in the learner, a lack of supporting empirical evidence for discovery learning methods, and the apparent drop in Albertan mathematics scores at various levels during times of inquiry learning being used in the classroom. Handelsman et al. (2004) raise an important question in the realm of science that has direct implications in the mathematics world in regard to teaching method, "Why do outstanding scientists who demand rigorous proof for scientific assertions in their research continue to use and, indeed defend on the bias of intuition alone, teaching methods that are not the most effective?” (p. 1). In the next section the research question, How does DI promote achievement in the middle and secondary school classroom?, will be investigated.

Direct Instruction in the Classroom

Introduction. The second research question that will be answered is, How does DI promote achievement in the middle and secondary school classroom? From the literature analyzed DI is correlated with student achievement and positive changes in student learning (Adams & Siegfried, 1996; Bakker, Smit, & Wegerif, 2015; Crane, & Brannen, 2008; Kinder, Ph, Carnine, & Ph, 2018; Kirschner et al., 2006; Lai & Murray, 2102; Mayer, 2004; Moreno 2004; Novosel, 2018; Stokke, 2015; Sweller 1988; Yeo, 2009). This is important because DI provides a deeper level of understanding and is a structured method of instruction that leads to student achievement at various levels for a variety of different types of students (Lai & Murray, 2102). There is empirical evidence indicating DI positively affects the learner and provides evidence for its use in the classroom, so the subthemes of deeper learning by DI, and structure for learning will be discussed in the following sections.

Deeper learning by Direct Instruction. DI supports learners by giving them the tools and strategies they need to learn without causing them cognitive overload (Kirschner et al., 2006). Empirical evidence has documented that via the use of DI, superior results have been achieved with a variety of students such as preschool, elementary, secondary school, and adult students (Adams & Siegfried, 1996; Kim & Axelrod, 2005; Przychodzin, Marchand-martella, Martella, & Azim, 2004). Included in those levels of students who experienced success with DI are regular students, special education students, and non-English speaking students (Adams & Siegfried, 1996; Przychodzin, Marchand-martella, Martella, & Azim, 2004). DI students outperformed students taught with all other teaching models, such as discovery learning, in all subjects (Adams & Siegfried, 1996; Kim & Axelrod, 2005) the research evidence also indicated a strong favoring of direct instruction over discovery based instruction for nurturing understanding, deeper learning and better problem solvers (Moreno, 2004; Stokke, 2015). Furthermore, no other models came close to student achievement for mathematics students taught with DI. Adams and Siegfried (1996) and Flores and Kaylor (2007) noted that students taught with DI preferred DI, were on task a higher percentage of time, showed better scores on comprehensive post-tests of the basics in mathematics, and showed a better attitude towards mathematics overall.

Stockard (2015) and Kinder and Carnine (1991) examined empirical evidence to point out that DI promotes higher academic gains than other forms of instruction such as Piagetian approaches, open classroom, parent-education approaches, and discovery learning. Students taught mathematics using DI learn more while developing positive views of their academic ability, give them a "running start at success" (Stockard, 2015 p. 7), and were at least one-half of a standard deviation ahead of all other instructional methods (Kinder & Carnine, 1991). Stockard (2015) and Kinder and Carnine (1991) conclude by stating that DI and DI principles should be used to teach basic and higher order skills and notes that DI is particularly useful in mathematics education and is associated with learner benefits such as 1) higher measurable achievement for students at the end of third grade that started DI in Kindergarten versus students that started it later; 2) significant gains and maintenance of IQ; 3) Low IQ students (under 80) also showed increases in IQ gaining nearly as much each year in reading and math as DI students with higher IQ; 4) follow up studies of fifth and sixth graders who received DI maintained their advantage with the strongest results seen on math-problem solving tests, and thus avoiding the "fourth grade slump" (Stockard, 2015); 5) middle year and secondary students who received DI in primary grades maintained their mathematical advantage over their peers not educated with DI and also had more success with college acceptance rates; 6) DI has proven successful across time, as follow up tests showed; and 7) DI also yielded exemplary results with populations of various demographics such as students from large and middle-sized cities, rural white and rural black communities, and Hispanic and Native American communities.

Stokkes' (2015) study regarding DI concludes from the research that DI methods such as directly taught concepts, explicit explanations, student practice using paper and pencil, feedback from the teacher, and conventional assessment are techniques that lead to student success. Stokkes describes DI as a bottom up approach in which students are taught the basics they need to approach a mastery level so that they are prepared for complex real-life problems.

Other studies noted additional benefits of using DI (Christofori, 2005; Flores & Kaylor, 2007; Gersten & Keating, 1987). Christofori (2005) observed that DI use led to higher-order problem solving, a mastery of basic skills leading to the ability to solve more complicated problems, immediate improvement in problem solving skills and across time, and all children involved with DI scored better overall after being taught with DI. Flores and Kaylor (2007) noted that through the use of DI students outperformed their peers taught fractions with other methods, maintained their performance after DI cessed, displayed more on task behavior, engaged more in lessons, and significantly improved their marks when comparing pre and post-tests. Gersten and Keating (1987) also noted a study showing evidence that high school students taught with DI in elementary grades achieved better on standardized tests, dropped out less, and applied to post-secondary more often than students taught with other means. Kirschner (2006), Moreno (2004), and Mayer's (2004) research supports DI versus other methods such as discovery learning, saying that DI, involving considerable guidance, produced vastly more learning. The direct guidance involved with DI helps the learner avoid the negative effects of inquiry such as acquiring misconceptions, associated with pure discovery learning, and taking them as fact (Kirschner et al., 2006). Learning erroneous information leads not only to a wrong answer but can be quite defeating for a student causing a decrease in motivation and a dislike for the topic whether it is in math or whatever topic is being discussed (Fullan, 2011). If DI was the method of instruction these misconceptions would be corrected and learners will get the help they need and proceed with the proper route of reasoning (Lai & Murray, 2012; Novosel, 2018).

Lai and Murray (2012) noted some educators prefer methods other than DI because DI makes use of rote learning. The examples Lai and Murray (2012) gave discussed the negatives to rote learning as the learner does not gain more understanding by repeating the same exercise over and over. Lai and Murray (2012) were also quick to point out that it is not that cut and dried, there are also benefits to making use of rote learning under a DI regime. According to their research being able to recall knowledge quickly that has been practiced many times helps ease the burden of recall and helps the learner toward a route of understanding. Repetition is therefore a powerful tool to help students deepen and develop their understanding (Lai & Murray, 2012; Novosel, 2018). Memorising, repetition, and understanding are linked together, and together help the learner develop a deeper level of understanding (Lai & Murray, 2012). Novosel (2018) adds to this by noting that students taught with DI tend to display better work habits and demonstrate mathematical rigor. Novosel (2018) says that due to discovery learning being the method of instruction presently in Alberta, the students have difficulty working on their own and need constant direction. Novosel (2018) offered two reasons for this 1) DI is more effective to promote deeper understanding, as was also previously mentioned by Lai and Murray (2012) and 2) with the present discovery learning model students lack the basics and foundation to allow them to approach problem solving on their own which contributes to a lack of personal confidence or mathematical ability.

Structure for Learning. The literature revealed there is a direct relationship between student achievement and DI using strategies such as worked examples and scaffolding (Clark, Nguyen, & Sweller, 2006; Kirschner et al., 2006; Mayer, 2004; Stokke 2015; Sweller 1988; Sweller & Cooper, 1985; Ward & Sweller, 1990). Feedback (Hattie & Timperley, 2007; Stokke, 2015) and explicit explanations (Kirschner et al., 2006; Stokke, 2015) were also identified as contributing factors to student success but will be discussed in the following section on metacognition where topics such as how students learn to think about what they are thinking to be successful in the classroom, will be discussed.

*Worked examples***.** Worked examples are taught with DI methods (Stokke 2015) and are defined as a "step-by-step demonstration of how to perform a task or solve a problem" (Clark, Nguyen, & Sweller, 2006, p. 190). Kirschner (2006), Sweller (1988), Sweller, Ayres, and Kalyuga (2011), and Mayer (2004) noted that use of worked examples led to better learning, especially in mathematics. For example, students who studied algebra using worked examples learned more by studying worked examples than by solving equivalent problems. Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) attributes learner success using worked examples to a decreased working memory load because the need to search for strategies is minimized and allows for freer progress from move to move. Research has shown that a three year math program has been successfully and effectively completed in two years using by directly instructing worked examples (Ward & Sweller, 1990). Ward and Sweller (1990) and Sweller, Ayres, and Kalyuga (2011) attribute this success to the schema acquisition and rule automation that come with studying worked examples. Ward and Sweller (1990) added to this by saying that worked examples focus attention on “problem solving states and their associated moves” (p. 36) allowing for more efficient learning, and Sweller, Ayres, and Kalyuga (2011) said “that learners have a decided advantage in studying worked examples” (p. 108) as they decrease the learners overall cognitive load. Kirschner (2006) agrees with this and noted that discovery techniques such as exploration practice caused poorer learning as compared to studying worked examples. The step-by-step guidance that comes of worked examples (Sweller, Ayres, & Kalyuga, 2011; Sweller & Cooper, 1985) has proven to be an effective method of problem solving.

Scaffolding. Scaffolding is known as the process that enables the learner to solve a problem, complete a task, and achieve a goal that would have otherwise been difficult for the learner to attain if left unassisted (Bakker, Smit, & Wegerif, 2015). Scaffolding is a step-by-step procedure that builds student skills needed to work with future higher levels of associated topics. DI makes use of scaffolding so there is a clear process of skill introduction, modelling the skill, guided practice, independent practice, assessment, review, and mastery (Crane, & Brannen, 2008) to see if all concepts have been grasped and correct lines of work are proceeding to advance towards a correct solution (see figure 5 below).

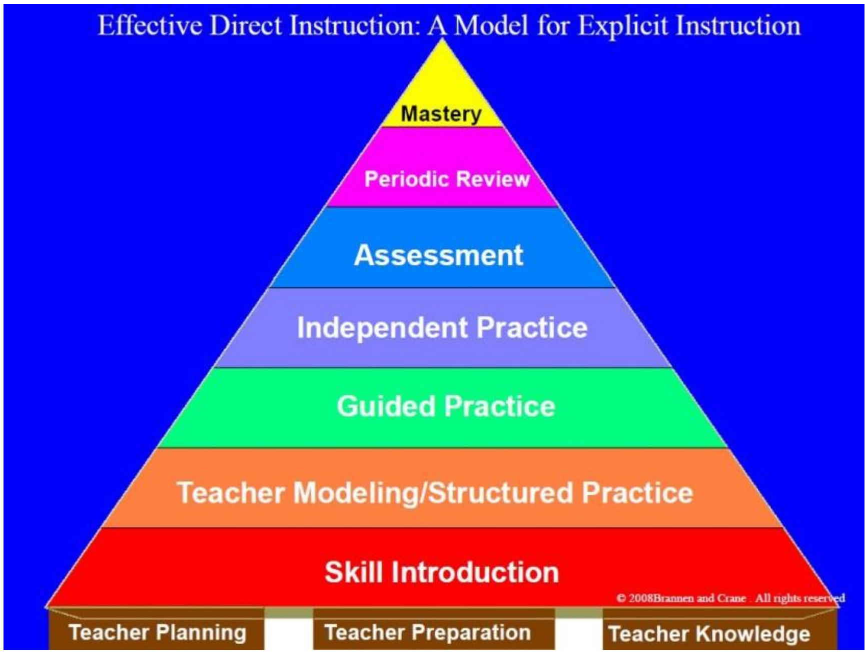


Figure 5. Effective Direct Instruction: A Model for Explicit Instruction

According to Bakker, using scaffolding in an educational setting, the instructor adapts their lesson to support the student, followed by a gradual withdrawal (fade) of support in hopes that the transfer of responsibility to the students occurs and the student is able to take responsibility. In other words, the teacher adapts their lesson, through DI guides the learner, then assesses the student either formatively or summatively to see if the material is retained, understood, and ready to be applied. Bakker also notes that scaffolding promotes student achievement and is particularly useful in mathematics. Novosel (2018) adds to this by noting that students at the middle years and secondary levels have difficulty working on their own due to poor scaffolding from the elementary level which leads to poor skills in later years of school. For example, students rely too heavily on calculator use when working with radicals, numbers involving the root sign. The learner tries to solve problems involving radicals without realizing that the calculator normally does not give the answers as exact values like a solution with the radical still in place. Students need to become comfortable with radical calculations first then later once they have a better understanding of them and can solve by hand they will be able to attain correct exact solutions; later the calculator can then be used to check their solution. By first teaching the students skills needed via DI, and assessing individual needs and differences, scaffolding the lesson helps the learner effectively learn how to solve problems with radicals ultimately on their own and in future scenarios.

Discussion. In summary, the question How does DI promote achievement in the middle and secondary school classroom?, has been answered. The research supports the use of DI to promote student achievement in middle and secondary levels for a variety of reasons. For example DI decreased cognitive load, works with many types of learners, promotes deeper understanding to be a better problem solver, math achievement is higher than other teaching methods, promotes more on task behavior, produces better post-test scores, enables better attitudes related to math, causes significant gains and maintenance of IQ, increased post-secondary acceptance rates, is effective to teach basic and higher order skills, avoids acquiring misconceptions as fact, and promotes rigor resulting in personal confidence and mathematical ability. Kirschner (2006) and Mayer's (2004) discussion about not using pure discovery, unless some form of guidance or scaffolding has occurred, illustrates the importance of how strongly correlated achievement is with guidance during instruction. They talked about inquiry only being okay after the necessary skills were taught, and even then, strong guidance is still needed for success. DI gives direct guidance in various forms, but the main two discussed thus far are worked examples and scaffolding. Evidence from the literature supports the use of worked examples and scaffolding to help the learner get the support they need and to succeed.

In conclusion, DI has demonstrated its positive effects on learning for the ways previously discussed. The research has shown that DI is a valid and effective method of instruction to help students of various levels, in particular middle years and secondary level students, succeed. Also noted was the success that mathematics students experienced when in structured environments using DI as the main method of instruction. In the following section the relationship between the learner, their thought processes, and DI will be examined by answering the question, How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?

Metacognition and Direct Instruction

Introduction. The third research question, How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?, will be examined in this section. The focus here will be to determine how DI and metacognition intermingle to help improve mathematical performance and competence for students studying mathematics. The reviewed literature supports the use of metacognition along with DI to improve student success in mathematics (Apaydin & Hossary, 2017; Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014; Farina, Weinberg, & Commitante, 2015; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; Stokke 2015; van Velzen, 2016). The evidence will be examined using two sub-themes and their associated topics, the subthemes are metacognition strategies and metacognition and mathematics.

Metacognition strategies. In general metacognition is higher order thinking in which the learner controls their own cognitive processes actively engaged in learning (Apaydin & Hossary, 2017). Metacognition is the process of thinking about your own thinking and research has shown that students who underwent metacognitive instruction exhibit higher cognitive skills than those who were not instructed about their own metacognition (Hattie, Fisher, & Frey, 2017). "Metacognitive strategies refer to the conscious monitoring of one's cognitive strategies to achieve specific goals” (du Toit & Kotze, 2009, p. 2). du Toit and Kotze (2009) mention a variety of metacognitive strategies such as planning strategy, generating questions, choosing conciously, setting and pursuing goals, and identifying the difficulty of a question, to name a few. For the purpose of this paper, however, some metacognitive strategies discussed which enable students to be successful, are self-questioning and reflection, and feedback. Also considered is metacognition and critical thinking.

Self-questioning & Reflection. Self-questioning is a process in which the learner thinks about their thinking by asking themselves questions as they move through the problem-solving process using question like “Does this make sense?” “Am I making progress finding a solution?” (Hattie, Fisher, & Frey, 2017, p. 185). Hattie proposes that to work through mathematical tasks the learner uses the self-questioning process to ensure metacognition development and successful completion of the problem-solving process. Hattie, Fisher, and Frey (2017) added to this that pre and post-lesson questions will help the learner develop their metacognition which again in turn aids their mathematical learning process. For the pre-lesson questions he suggests “What are today’s goals?” “How much do I already know about today’s goals? and for the post-lesson questions he suggests What was today’s goals? Did I achieve this goal?” (Hattie, Fisher, & Frey, 2017, p. 186). By encouraging this type of process learners are encouraged to develop unpacking strategies that they can actively use and purposefully contemplate. Hattie suggests self-reflection as a process to act as a self-check system once the self-questioning process is complete. This is effective because it serves to assess what the learner has actively processed metacognitively and what they have truly learned. The process of self-reflection helps the learner understand where they were and where they are now so that they have a method of thinking about what they think about during the problem-solving process.

Heemsoth and Heinze (2016) agree that the process of reflection is an effective method to help the learner process what they are thinking during problem solving. Heemsoth and Heinz (2016) confirmed the importance of self-reflection and its application by assessing the ability of grade seven and eight students to work with fractions. Their research supports the notion that reflection on errors will enable a student to think deeper and in more detail. They noted students that reflected on their own errors (error-centered condition) versus students that were just shown the correct answers to study (solution-centered condition), experienced more effective learning and better knowledge acquisition. This increased ability lead to a significant increase in grades and overall performance and satisfaction in mathematics.

Doll (1993), Lewis (2004), and Luo (2004) also saw the value in reflection by expressing their beliefs in the value of the 4R's; Richness, Recursion, Relations, and Rigor. The second R, recursion, is related to reflection. Recursion is the idea of analyzing phenomena, formulating thought about it, reflecting on that thought, analyze again, formulate another deeper thought, and reflect on it once more (Doll, 1993; Luo, 2004). Doll (1993) says, "in recursion, reflection plays a positive role; for thoughts to leap back on themselves" (p. 256) and continuing these processes is what leads to higher level thinking, also known as critical thinking, by the learner. Luo (2004) also points out the importance of thoughts leaping back on themselves so that the learner can develop competence in the form of organized thought allowing the learner "to figure out patterns and to jump to a higher level of learning" (p. 9). Lewis (2004) backs up the importance of reflection when she discussed how recursion in the form of metacognition was used to help the students reflect about topics of study to broaden and deepen their daily oral language to be applied in new situations and adapted as necessary. By using this continuous process Doll (1993), Lewis (2004), and Luo (2004) are pointing out that in curriculum filled with recursion there is no beginning and no end and that students should be encouraged to continue this process to transform the mind. This transformation will enrich the learners' experience in a variety of settings so that they can so that they can make use of their newly learned reflective critical thinking ability. Reinholz (2016) also believed in a recursion like cyclical process of reflection where one type of reflection is the beginning of the process, prospective, and the other the end, retrospective. Reinholz (2016) discussed the prospective reflection as the type that guides the learner's actions during a learning experience and the retrospective reflection as one that consolidates what was learned to be used in the next prospective learning phase or new learning experience. Reinholz (2016) notes that prospective reflection is particularly useful in mathematics because it helps the learner notice relevant elements of a problem and act accordingly allowing them to be more engaged within the context of the problem. "By developing the ability to reflect prospectively, individuals can learn to guide their actions in new ways" (Reinholz, 2016, p. 445) during the process of problem solving, and in future problem-solving scenarios. The idea is to have the student learn to reflect retrospectively and prospectively together to help the learner know what to focus on when problem solving. When this happens knowing what to attend to becomes automated, enabling the learner to reflect more efficiently prospectively during a learning experience so they can focus on pertinent details during the learning experience instead of just reflecting on them after the experience has ended. Reinholz (2016) noted that it is the continual use of the combination of retrospective and prospective reflection, that enables the learner to change their prospective reflection in future problem solving scenarios and allows the learner to change what they attend to when problem solving.

Feedback. Helping learners improve their metacognitive knowledge and their metacognitive processes is achieved by providing them with feedback (Stokke, 2015). Feedback is defined as "information provided by an agent (e.g., teacher, peer, book, parent, experience) regarding aspects of one's performance or understanding" (Hattie & Timperley, 2007, p. 81). Feedback can take the form of "comments and more instructions about how to proceed, clarification, criticism, confirmation, content development, constructive reflection, correction (focus on pros and cons), cons and pros of the work, commentary (especially on an overall evaluation), and criterion relative to a standard" (Hattie & Yates 2014, p. 64). Hattie, Fisher, and Frey (2017) discusses the timing of feedback noting that if dialogic approaches, teaching based on discussion and waiting before giving feedback, were used feedback would not occur immediately but instead more towards the end of a problem-solving exercise as compared to immediately if using more of a direct teaching method. In another paper by Hattie and Yates (2014) he elaborates on this by saying that immediate corrective feedback and error correction during task acquisition causes better learning of topics studied especially at the process level on tasks like classroom activities. This falls in line with the DI methods and procedures aimed at helping learners of mathematics acquire and accommodate new knowledge and problem-solving procedures. Immediate performance feedback has shown to improve student knowledge acquisition (Kollöffel & de Jong, 2016). Kollöffel and de Jong (2016) studied the effect of immediate social comparison feedback and discovered that having feedback, during instruction, contributed to significant learning gains on pre and post-test scores. This type of approach is also supported by advocates of DI methods to ensure smooth transition of learning to minimize learning erroneous problem-solving strategies (Kirschner, 2006).

Critical Thinking. The metacognitive skills previously mentioned help the learner to build their critical thinking capacity (Magno, 2010), which leads to better problem solving ability. Critical thinking is the objective analysis and evaluation of a situation to come to a conclusion about a scenario observed or experienced. “Critical thinking occurs when individuals use their cognitive skills or strategies that increase the probability of a desirable outcome” (Magno, 2010, p. 1). By making use of metacognitive skills to develop critical thinking ability the learner activates many metacognitive skills, such as self-monitoring, reflection, and various forms of knowledge, to achieve higher order thinking (critical thinking) in order to solve a problem.

Metacognition and mathematics. Since metacognition does not automatically develop in the learner, educators play a key role in the education of metacognition to students to encourage development (Baten, Praet, & Desoete, 2017). “Mathematics educators should explicitly instruct metacognitive knowledge and model metacognitive skills” (Baten, Praet, & Desoete, 2017, p. 620) to the learner to maximize mathematical achievement. Baten et al. (2017) suggest using DI as well as a variety of other methods such as reflective journal writing, strategic questions, and reflection questions to metacognitively train secondary school students. Baten et al. (2017) also suggest starting metacognitive education in kindergarten to minimize the gap between students who have differing levels of exposure to metacognitive strategies in hopes that metacognitive knowledge will be better in later years of their education, which leads to better mathematical achievement.

Metacognition and DI are both focused on clear organized structure to help students go from a first thought all the way to the finished product. This structured line of thinking is also supported by Blooms taxonomy, old and new version, in that knowledge or strategy gained can be applied and used in new and unfamiliar scenarios within the math classroom (Forehand, 2011). In addition to this, in regards to strategies creating success, Blooms taxonomy clearly indicates that metacognition and metacognitive knowledge is tantamount in attaining educator and student goals. The revisions to Blooms taxonomy lays out a formula consistent with DI practices for cognition and achievement success by highlighting the importance of factual knowledge, conceptual knowledge, procedural knowledge, and the aforementioned metacognitive knowledge (Krathwohl et al., 2002); this can be seen by examining the similarities between DI and Blooms taxonomy in Figure 6 & 7.

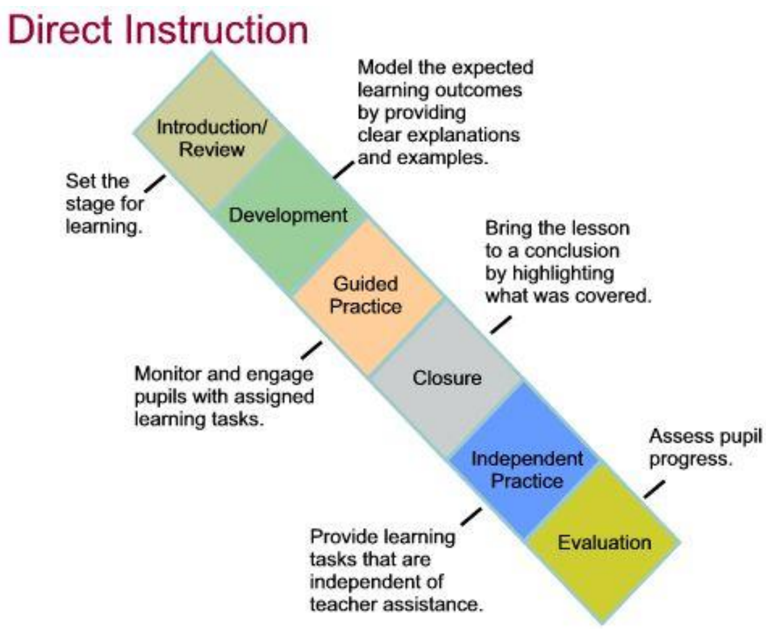


Figure 6. Direct Instruction

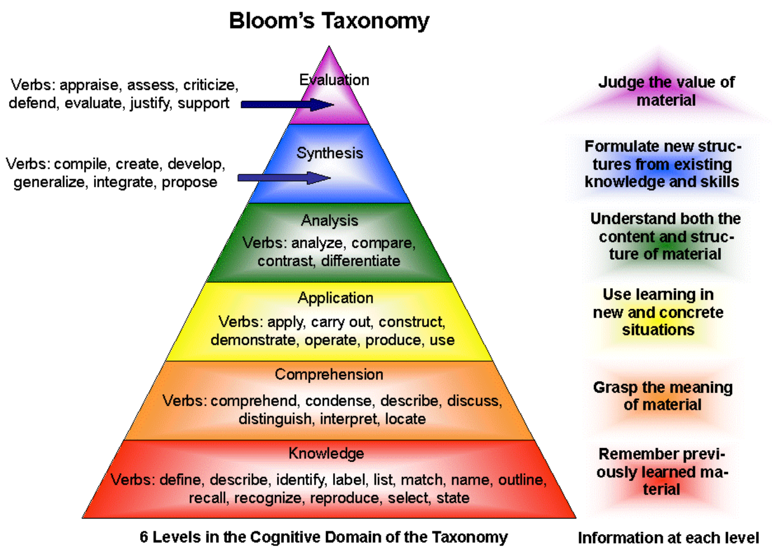


Figure 7. Bloom's Taxonomy

DI's review, development, guided practice, closure, independent practice, and evaluation are similar to Blooms taxonomy structure of knowledge comprehension, application, analysis, synthesis, and evaluation respectively. Using these steps to teach the learner metacognitive strategies will lead to a continual cyclical process (figure 8) of assessing the task, evaluating strengths and weaknesses, planning an approach, applying strategy and monitor performance, and reflect and adjust to the topic studied as needed (Ambrose, 2010; Franco, n.d.).

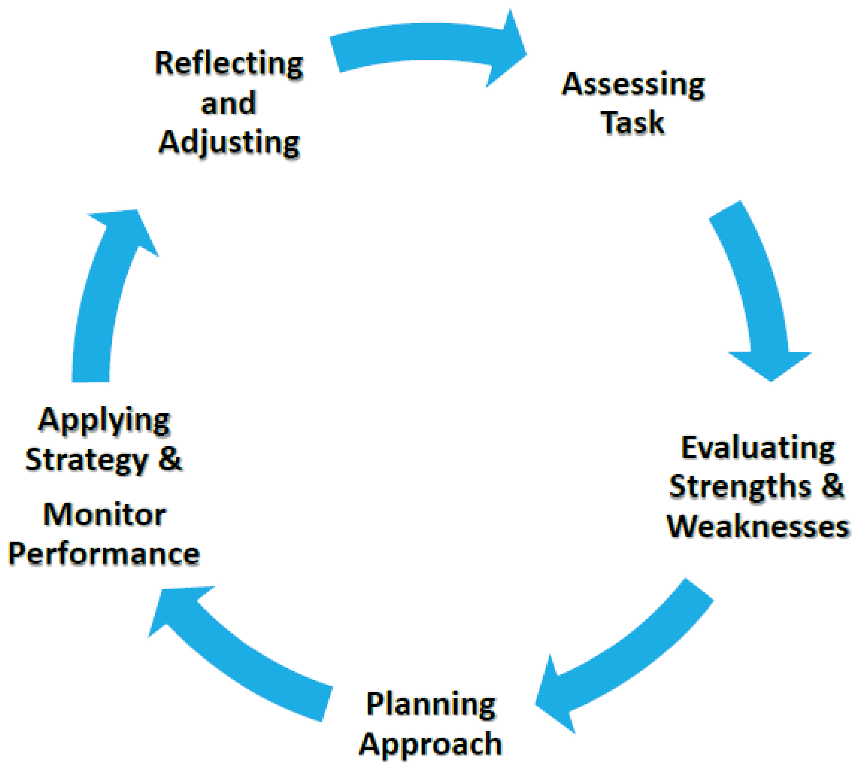


Figure 8. Metacognitive strategies

Math Literacy and Numeracy. Math literacy is the idea that not only do students know the language and vocabulary of math but also have the ability to analyze, reason, apply, and solve problems in familiar and unfamiliar contexts. According to the disciplinary literacy model (Farina, Weinberg, & Commitante, 2015) every subject has its' own set of language, terminology, and procedures that students need to know. For example to be mathematically literate students need the "ability to understand and solve complex problems, read and comprehend complex tasks, and write, speak about, and question their own and others' solution paths" (Farina, Weinberg, & Commitante, 2015, p. 15). The subject of math is its own language with numerical and non-numerical symbols that the learner needs to decipher before meaning can be made from a problem, and the problem solved. Math textbooks also have diagrams and side bars that may be related to the problem at hand so students need to be well versed mathematically.

To ensure this happens the math literacy metacognitive processes required to problem solve need to be explicitly taught to students for the best chance of success (Farina, Weinberg, & Commitante, 2015). According to Farina et al. (2015), these metacognitive strategies include think alouds, visualization, using guiding questions, writing about mathematical questions and reflections, directly discussing and unpacking the language used in problems, defining function words such as “the” and “a”, defining the vocabulary such as prime numbers or mean, using word walls, and discussions regarding problems to allow for immediate feedback. Farina et al. (2015) also promote the use of funneling, use of questions to arrive at a pre-established procedure, or focusing, listening to what students say to indicate their thoughts and how they communicate with others, to promote deeper mathematical learning. By directly teaching these metacognitive techniques, it is thought that the educator will enable the learner to be metacognitively and mathematically successful, and mathematically literate.

Numeracy is the ability to reason critically about quantitative data (Gittens, 2015) and will help students be successful in and out of the classroom environment. Numeracy is also “the confidence and habits of mind to engage with, critically assess, reflect upon and apply quantitative and spatial information when making judgements an decisions or taking actions in all aspects of daily living” (Edmonton Catholic, 2015, p. 2). Edmonton Catholic Schools District (ECSD) believes it is important to have a good sense of numeracy (Edmonton Catholic, 2015, p. 2), as is indicated by the allotment of significant funds towards mathematical numeracy in the form of teacher professional development (PD), development of math and numeracy community at various levels of education, out of district presenters, as well as a plethora of other forms of numeracy development. To this end ECSD has also promoted numeracy to its educators and students, with the goal of raising student numeracy awareness, by sending out yearly emails for what is called numeracy week, on topics such as symmetry, composing, decomposing, transforming shapes, locating, mapping, orienteering, coding, and perspective taking. There is also π (Pi) day on March 14th detailing how π came about and how it is used. This focus on numeracy comes directly from the ministerial order (Government of Alberta, p. 3, 2013) to ensure that the learner is making use of the metacognitive strategies mentioned previously to maximize numeracy education to help the learner be better equipped to solve mathematical problems.

Discussion. From the research about the third question, How can metacognitive strategies be combined with DI to improve student outcomes in mathematics?, the answer is to teach metacognitive strategies explicitly to students of mathematics using DI to ensure deeper learning and success. DI was explicitly mentioned to aid in metacognitive strategy attainment (Baten, Praet, & Desoete, 2017; Farina, Weinberg, & Commitante, 2015). Topics that surfaced across the research in regards to metacognitive strategies were self-questioning & reflection (Baten, Praet, & Desoete, 2017; Hattie, Fisher, & Frey, 2017), feedback, strategic questions, and a focus on developing metacognitive processes to develop the learners' critical thinking (Doll, 1993) skills, and formation of more efficient prospective and retrospective reflections (Reinholz, 2016), to maximize mathematical achievement. The research suggested that learning and metacognitive strategy acquisition is a cyclical process (Ambrose, 2010; Franco, n.d.) that can be directly instructed, and once learned by the student can be used to continually assimilate, accommodate, and adapt their schemas to new information through a reflective process. To ensure this happens ECSD has devoted significant amounts of money and time to educate students metacognitively in the form of numeracy (Edmonton Catholic, 2015). Numeracy is in the ministerial order (Government of Alberta, 2013) and has been adopted by ECSD so that students can learn to use metacognition to better their mathematical studies and personal growth.

Summary of Findings for the Three Research Questions

Based on the findings, this review has answered the following three questions: 1) What support can be found in the research for using Inquiry Learning for the mathematics classroom? 2) How does DI promote achievement in the middle and secondary school classroom? 3) How can metacognitive strategies be combined with DI to improve student outcomes in mathematics? The research has indicated that there is not enough evidence to support the use of inquiry learning without strong guidance and previously taught supporting knowledge. Overall it is not a recommended method of instruction and has limited empirical evidence that it is an effective teaching method, especially when considering mathematical education. DI has a variety of empirical evidence showing that it is an effective method of instruction, which has shown to promote deeper student mathematical learning, lasting long after instruction. DI has also shown to be strongly favored over discovery learning because DI nurtures the learners' understanding and learning process to aid in deeper learning to help them be better problem solvers. The empirical evidence also suggests that DI of metacognitive strategies promotes metacognitive knowledge and mathematical success. The research and empirical evidence is mainly from educational settings such as elementary, middle school and secondary levels. To give students the best chance of success and based on this literature review it is recommended that educators make use of DI and DI of metacognitive strategies to help students be mathematically successful. If inquiry learning is to be used, it should only be done so after the supporting knowledge and skill has been directly instructed and understood through the processes described in this paper and with strong guidance and explicit explanations.

The next section of this paper will contain a project aimed at providing professional development (PD) to educators about the information contained within this literature review. By creating a PowerPoint PD, my goal is to disseminate the main points of what was learned and discussed in the literature review in hopes that educators at various levels will take away useful knowledge that they can apply to their own profession.

Master's Study Experience

The Project

What I did? From the literature I researched and reviewed topics related to inquiry learning, DI, and metacognition within educational settings such as the mathematics classroom at the middle and secondary levels. I discussed evidence about the effectiveness about inquiry learning, DI, and how to relate metacognition with DI to help students achieve mathematically. I included topics that were directly related to literature from time periods that go back to the 1960's up until the present time period of 2018 in hopes that educators find something useful from what educators and researchers already know and have employed in the classroom. I presented the findings in a straight forward manner to help other educators gain an understanding of what the literature says about the education techniques that are used in the classroom and their effectiveness.

What I made? I chose to share what I learned by making a PowerPoint presentation outlining all the major findings with their supporting evidence directly linked to what is documented in the supporting literature. I built slides that do not overwhelm the audience visually and included clear links to the research and supporting notes for each slide on the notes pages attached to each slide. The material has been presented in a manner that provokes the audience to think about the different instructional methods touched on and their use of these techniques. The PowerPoint itself is designed for a half day professional development (PD) for educators of various types; I have attached the PowerPoint at the end of this document, it can be found in the appendix. The information presented is applicable to educators at all levels of instruction whether that be elementary, middle, secondary, post-secondary, or adult education and for learners of various abilities.

What I thought? The purpose of researching the topics of inquiry learning, DI, and metacognition tied in with DI was to gain an understanding of what the research says about those topics, compare discovery learning with DI, and analyze how to incorporate metacognition to help students be mathematically successful instead of only doing a comparison of discovery learning and DI. Using this approach I think that educators, myself included, will be better informed and can make decisions based on what the research says so that they have a broader understanding, while making choices related to student success.

Master's Reflection

Introduction. The purpose of this section is to outline and share my growth and experience throughout this M. Ed. studies program. I will reflect on my experience in the following sections; personal growth, professional growth, and my contributions to the profession.

Personal Growth. Partaking in a master's program has afforded me the opportunity to better myself personally in regards to broadening my knowledge base and experience. I have learned many things during this program that have depended my understanding of what exactly goes into the process of research, writing, publishing, knowing where to publish, knowing where to find credible information, and how to know if publishers are credible. Having a master's allows me to feel confident that what I say or write about is true and has been backed by research and has been through a strict process of review to ensure accuracy and truth. I also feel a personal sense of satisfaction that I can say I have a master's and that I have bettered myself and learned new and valuable information.

Since the beginning of this master's program we have been studying different ways to prepare our students for the future. Topics discussed focused on curriculum and ideologies surrounding the best way to deliver curriculum and what exactly should be included in the curriculum. The history of scientific methods, which is applicable in many fields today, what it means to be a behaviorist or a constructivist with their associated authors, and the plights of different people and people with different orientations were explored, discussed, and researched. These topics and many more have helped me become a more informed and well-rounded person; I valued the learning experience of the whole program including the material learned and the very helpful teachers that guided me along this journey.

In regards to why I chose to pursue studying discovery learning, DI, and metacognition with DI, I wanted to research what the literature said about the effectiveness of discovery learning compared to DI because of the students that I see in my own profession struggling with mathematics. I wanted to understand if it was just a perception of the public to blame discovery learning or if there was something academically to back up the idea that using discovery learning by itself was not good enough to aid student learning. From what I read in the literature it is not just public perception, the literature also suggests that discovery learning is not a good idea to use by itself. There needs to be teaching of foundational knowledge and background followed by strong guidance to allow the learner the best chance of success, short and long term, and the research shows that DI is a good choice to help achieve student success.

I also wanted to expand my thoughts and research to an area that goes beyond a comparison of two types of instruction to metacognition. I wanted to expand my knowledge of how to help students succeed mathematically and I thought a good way to do this would be to better my understanding of how to help the learner in terms of metacognition strategies. I am pleased to say that I was able to find many strategies that I discussed in the literature review that are effective and valid techniques in the classroom. Having an awareness of one’s own thinking processes, and using metacognitive strategies to promote this, students are better equipped for future learning contexts and will have more success when trying to achieve their goals.

Professional Growth. During my studies, within the department of curriculum and instruction I have learned about many different topics and perspectives such as curriculum as discourse, various selected topics in curriculum and instruction, teaching culturally and linguistically diverse students, emerging trends and topics in curriculum, research methodologies in education, and instructional leadership and change. All of these topics have enriched my development professionally. I have a better understanding of how the profession of education itself has evolved and the battles that have played out to gain the respect needed to be called professionals.

We, as professionals, owe it to ourselves, as educators, to be the best version of ourselves so the students can do the same on their educational journey. By continuing my own studies and professional development I am making myself more knowledgeable and informed so that I can provide the best opportunity for student success, and success of my coworkers. In the process of continuing my own education, I am also providing for my own future opportunities professionally if I wish to pursue administration in the future. I enrolled in this master's program to enrich my own learning but if I want to pursue administration then this program has helped me become more well-rounded and prepared to lead.

Professionally, I chose to study what the literature said about my topics of inquiry learning, DI, and metacognition for the same reason I mentioned in the personal growth section, I wanted to know what the research said about the effectiveness of the instructional strategies. However, professionally, the reasons are for more than just personal curiosity. Keeping myself informed by the literature, has enabled me to make adjustments to my own teaching, and share what I learned with other professionals, to give the students the best chance of success. For example, I have already been using more of a DI approach in the classroom, which the students do very well with academically, but I have also been incorporating metacognitive strategies to get them to think about what they are actually reading while trying to problem solve. Things that we as a class have discussed include chunking information to make it more manageable, analyzing what the words, vocabulary, and numbers mean in the context of the problems, critically thinking about self-questioning and reflections, listening to and reflecting on feedback, and becoming more aware of what it means to be mathematically literate with an understanding of numeracy.

My Contribution to the Profession. By undertaking this journey of self-evaluation and enrichment, through studying the literature and the master's program overall, I have continued my journey as a lifelong learner. In doing so I have used what I have learned, and continue to learn, to make myself, students, and fellow educators more informed and more equipped to adapt to future problem solving scenarios. By using what I have learned to help students achieve they are more likely to succeed. In regards to other professionals, in the field of education, my contribution to them is to provide PD to inform them of the literature so that they can also make use of it in their educational settings for the betterment of student learning. The PD is in the form of the project previously mentioned and can be found in the appendix. Other ways to contribute to the professionals in my profession are to inform them of what was written in other articles that I read during my studies as a graduate student, or by simply pointing out the difference between using an oxford comma and not using an oxford comma.

Conclusion

My journey as a teacher shifted to one of a researcher while studying, and it now shifts back to an educator's role, whether as a teacher or administrator, to continue teaching on the front line sharing what I have learned from a very rewarding master's program. As a teacher that has done the research, and is informed by the literature, I am able to use the research to better teach the youth of today to help create a rich and promising tomorrow.

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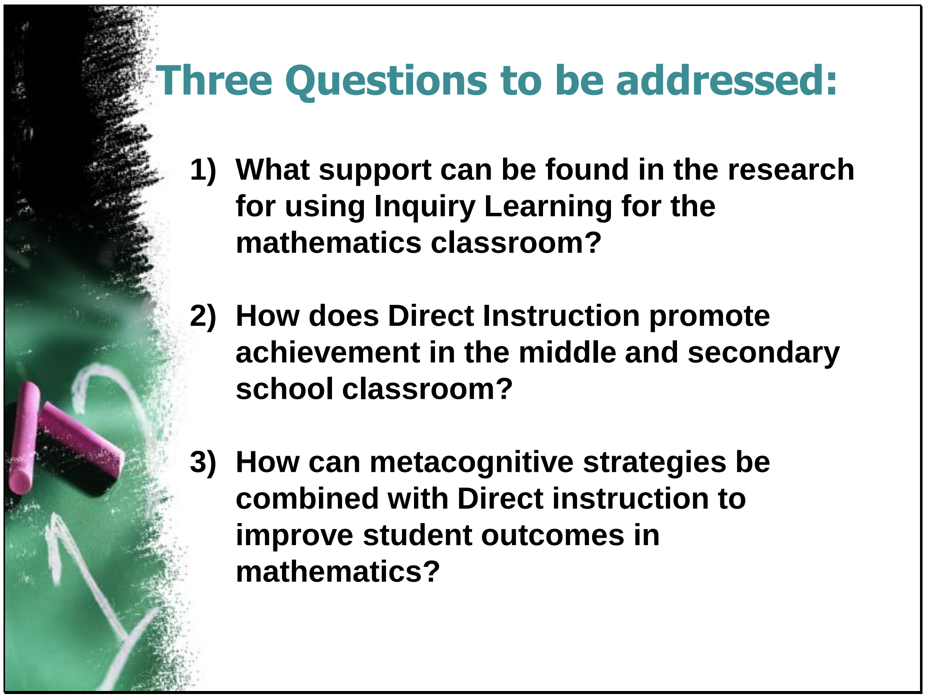
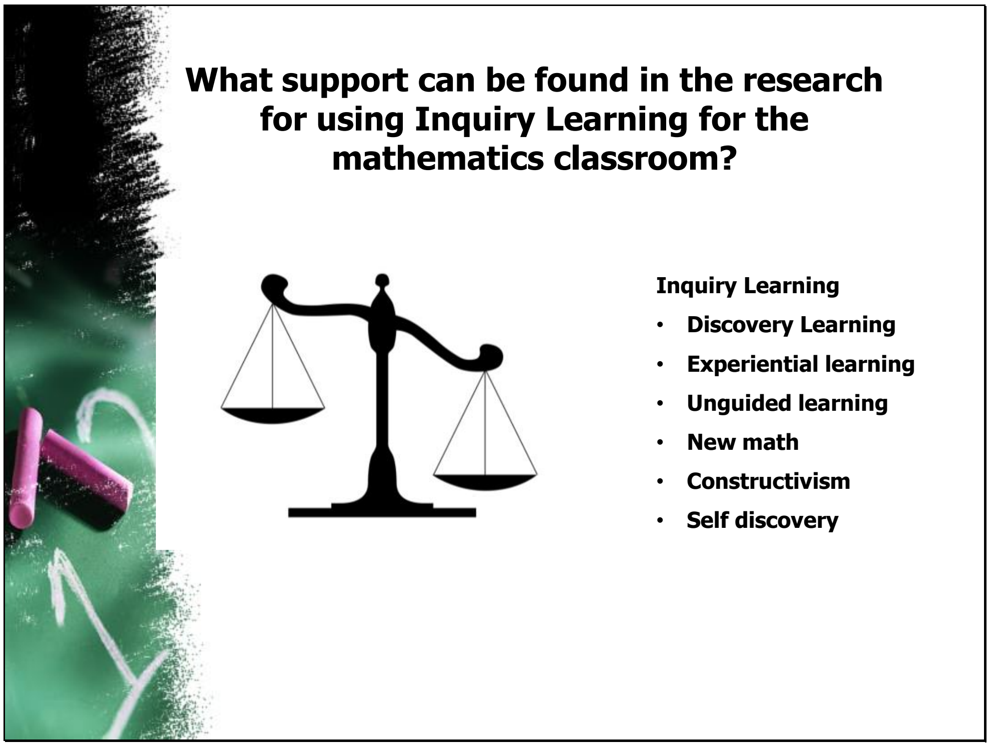
Appendix

Slide 1

Slide 2

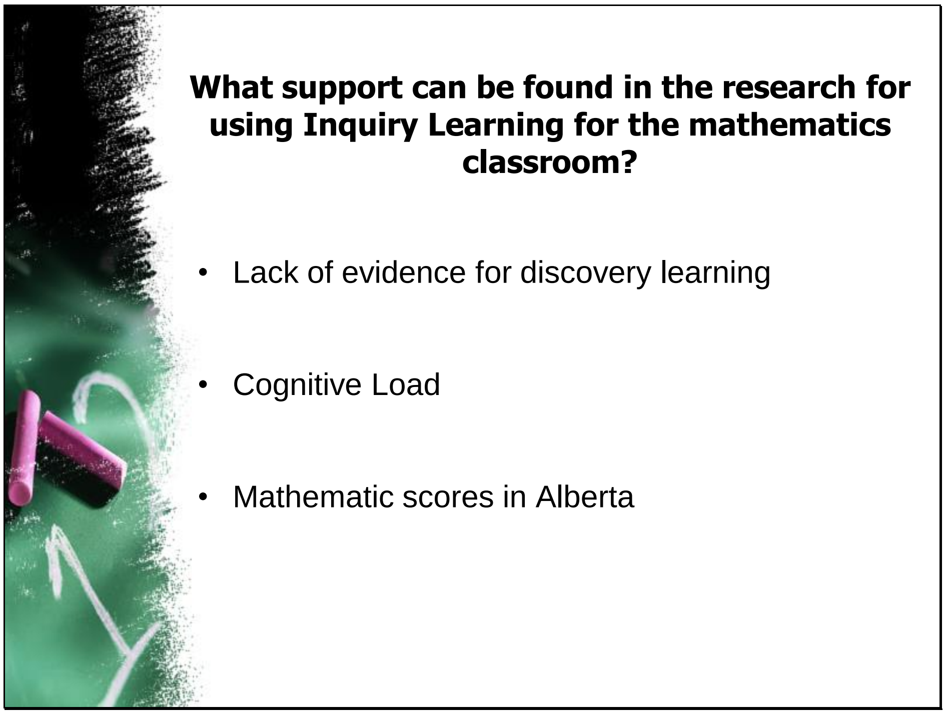

Three Questions to be addressed:
1) What support can be found in the research for using Inquiry Learning for the mathematics classroom?
2) How does Direct Instruction promote achievement in the middle and secondary school classroom?
3) How can metacognitive strategies be combined with Direct instruction to improve student outcomes in mathematics?

Slide 3



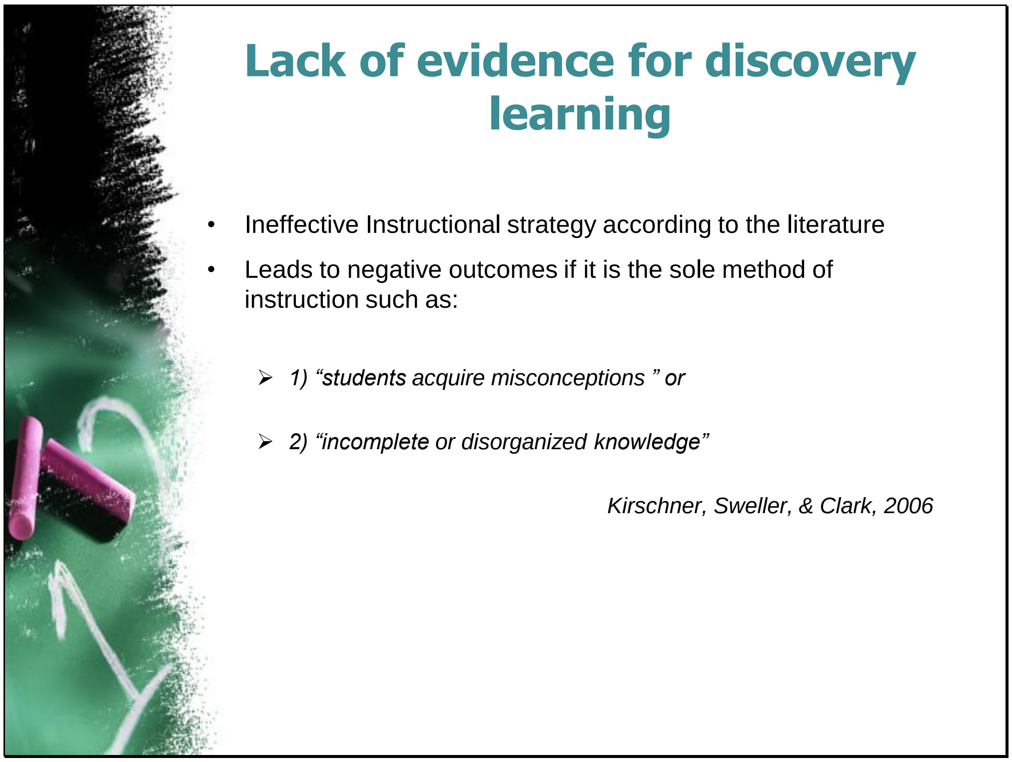
There are many terms for Inquiry Learning, these are just a few that educators use to describe Inquiry Learning. Knowing the vocabulary will help to understand to which method a key term is referring.

Slide 4



These are three sub-themes that surfaced in a literature review on the question, What support can be found in the research for using Inquiry Learning for the mathematics classroom?

Slide 5



The main challenge of inquiry learning that arose from the literature is that there is concern that it is an ineffective instructional strategy leading to negative outcomes (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Duffy & Tobias, 2009; Kirschner et al., 2006; Paas, Renkl, & Sweller, 2003, 2004 Sweller, 1988).

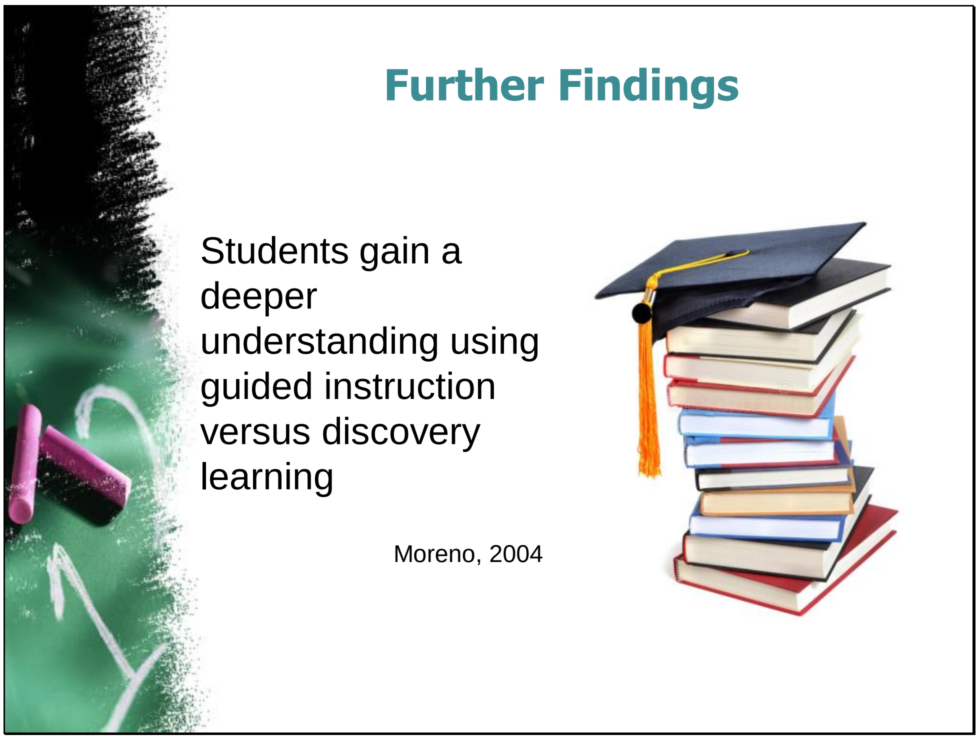
For example, Kirschner et al. (2006) stated in their conclusions that use of less guided instruction such as inquiry learning is less effective and evidence suggests "that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge" (p. 84). As pointed out earlier, even an inquiry learner supporter like Dewey (1910) says that there needs to be guided instruction first to set the learner on the correct path and avoid forming incorrect conclusions. Kirschner also reviewed meta-analysis data on a variety of sources such as quantitative, qualitative, and theoretcial studies such as dissertations and articles and concluded that the data does not support the use of inquiry instruction.

Slide 6

Kirschner cautioned against thinking that pedagogic content is similar to and replaceable by the methods and process that go along with inquiry; knowledge learned is valuable and should not be replaced with a focus on how to solve a problem without having the tools or prior knowledge. The process of building a knowledge base from which to draw upon for future problem solving scenarios requires the intentional aquiring of strategies to adapt to and solve problems; experts did not become experts overnight, they accummulated experience to grow knowledge slowly, and this cannot be replaced with inquiry learning (Dehoney, 1995; Kim & Axelrod, 2005).

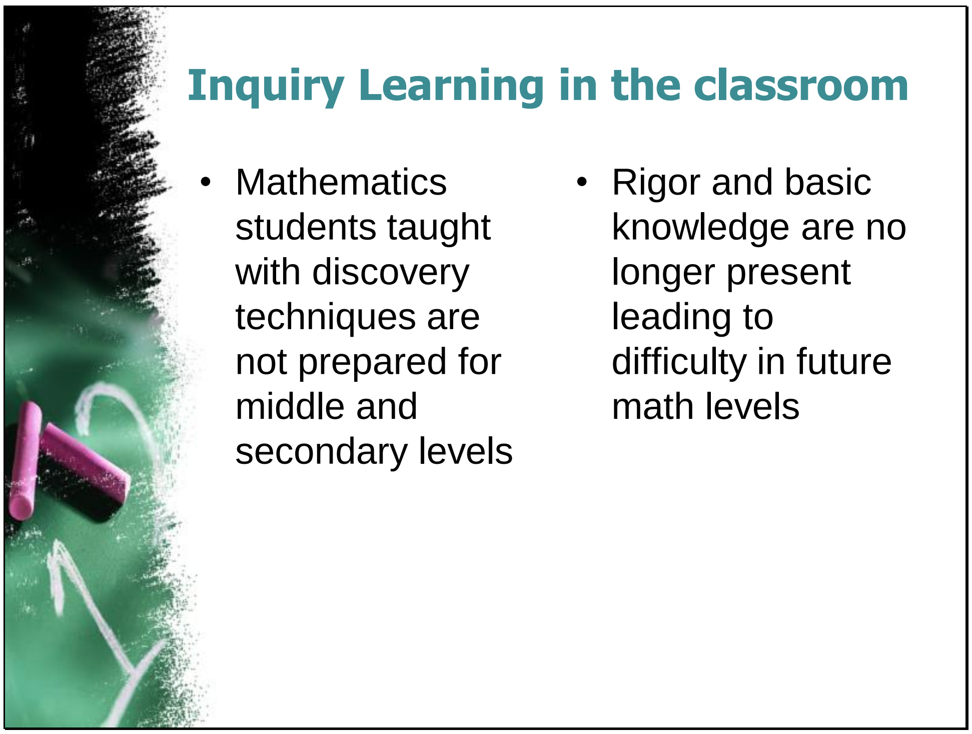
Kirschner points out a couple other pieces of research (Handelsman et al., 2004; Hodson, 1988) that add to this by noting that by using more of a constructivist method there is a shift away from teaching as a discipline with a focus on knowledge to one with a focus on process and procedure. When inquiry is used instead, it gets the learner to try to learn by doing but the process is not explained or discussed so the why or how something works is not truely learned; additionally in some cases the students actually knew less after being instructed with discovery learning than prior to the lesson (Kirschner et al., 2006).

Slide 7



Findings about discovery generally stated there is not enough supporting literature to consider using it as the sole method of instruction (Alfiere, Brooks, Aldrich, & Tenenbaum, 2010; Duffy & Tobias, 2009; Kirschner et al., 2006). In fact, some go as far as to say that there is a growing body of evidence indicating that students gain a deeper understanding using DI versus discovery learning (Moreno, 2004). Kirschner et al. (2006) would agree and add that from the available studies, the literature almost uniformly supports the strong direct guidance of DI versus constructivist discovery learning. Also noted was that even if students have a strong foudation of knowledge to build on they still need strong guidance to succeed.

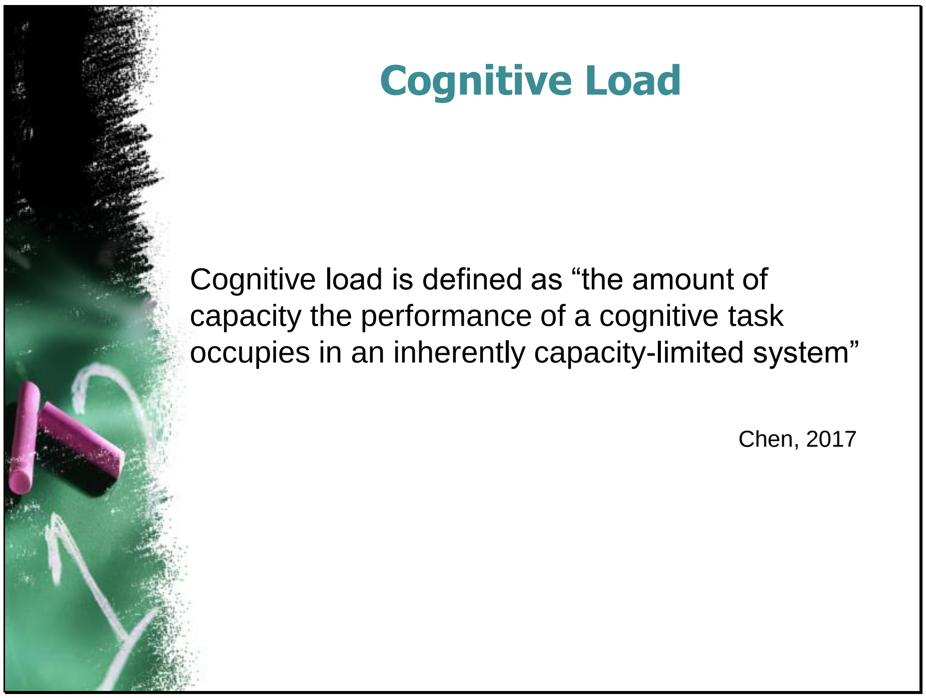
Slide 8



Novosel (2018) has indicated that since discovery learning has been implemented, students taught with inquiry methods are unprepared for mathematics at the middle years and secondary levels.

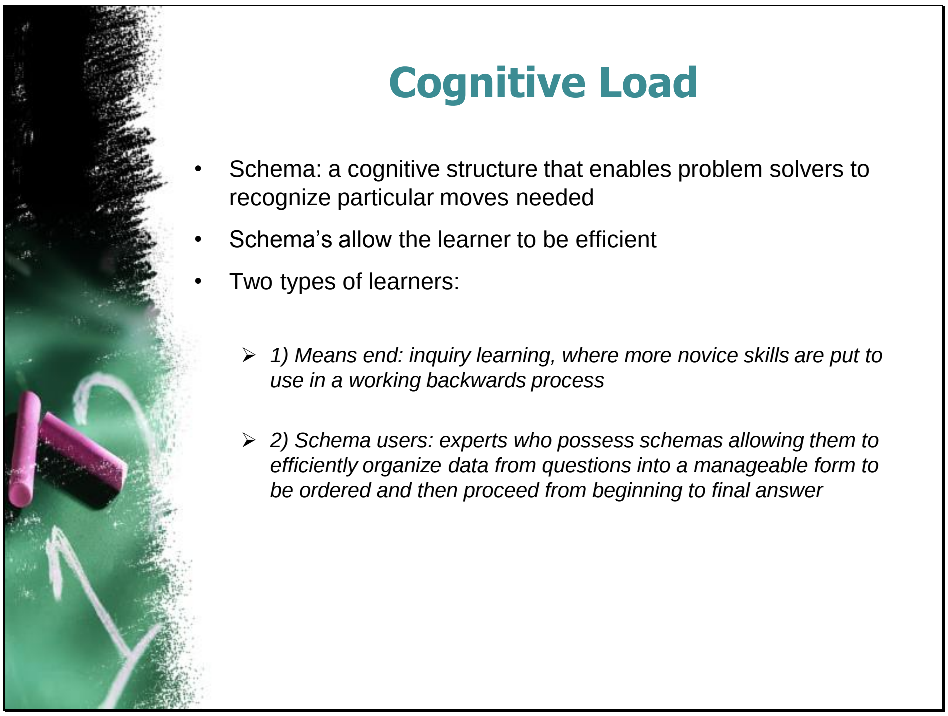
More specifically, Novosel (2018) comments that mathematical competence has decreased along with the rigor needed to be successful, leaving students unprepared for future math classes. Novosel goes further by saying that many students now struggle with basic skills like, multiplying, adding, subtracting, dividing, fraction work, percentage work, order of operations also known as BEDMAS (brackets, exponents, division, multiplication, addition, subtraction), decimals (all operations & rounding), exponent work, surface area, solving equations, and solving equations with fractions. According to him it is clear that educators are not preparing students for the future while using inquiry tactics because students are now unable to handle the rigor expected of them in high school, unable to keep up with the amount of material due to lack of basic skills, have poor work habits, and are less disciplined when it comes to doing what they need to be successful mathematically

Slide 9



In short cognitive load is the effort used in working memory while working on solving a problem.

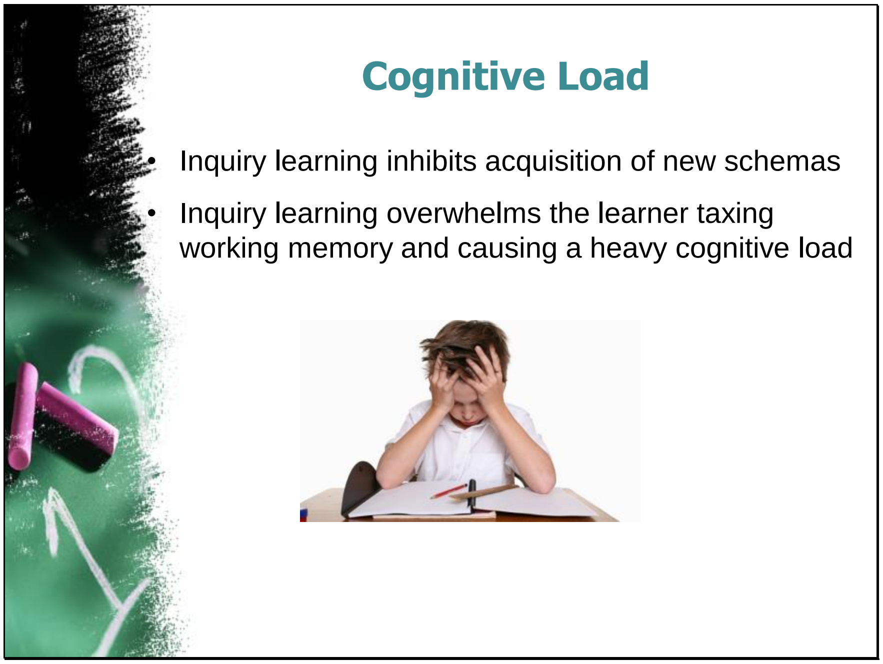
Slide 10



In relation to cognitive load and structure, Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) studied two types of problem solvers to answer the question "Why should some forms of problem-solving search such as means-ends analysis interfere with learning?" (Sweller, 1988, p. 5). He defines one type of problem solver as a means-end type, inquiry learning, where more novice skills are put to use in a working backwards process versus experts who possess schemas allowing them to efficiently organize data from questions into a manageable form to be ordered and then proceed from beginning to final answer.

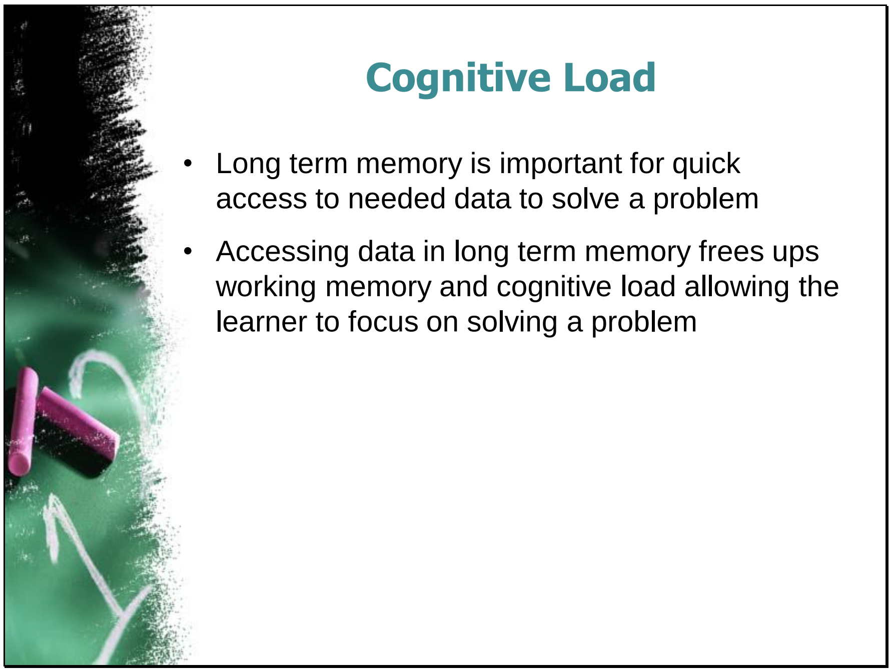
Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) state it is the schema, a cognitive structure that enables problem solvers to recognize particular moves needed, that allows the learner to be efficient. It is this efficiency that frees up cognitive space allowing for true learning to happen. In their studies it is stated that having more structured cognitive architecture with pre-learned procedure, schemas, will aid in decreasing cognitive load.

Slide 11



The literature suggested that students being taught with minimal guidance are being overwhelmed because they were not taught foundational skills and lack the schemas needed to solve problems but are now being expected to use their working memory to solve problems when their working memory is already taxed trying to figure out new strategies or create new skills to deal with unfamiliar questions (Kirschner, Sweller, & Clark, 2006).

Slide 12

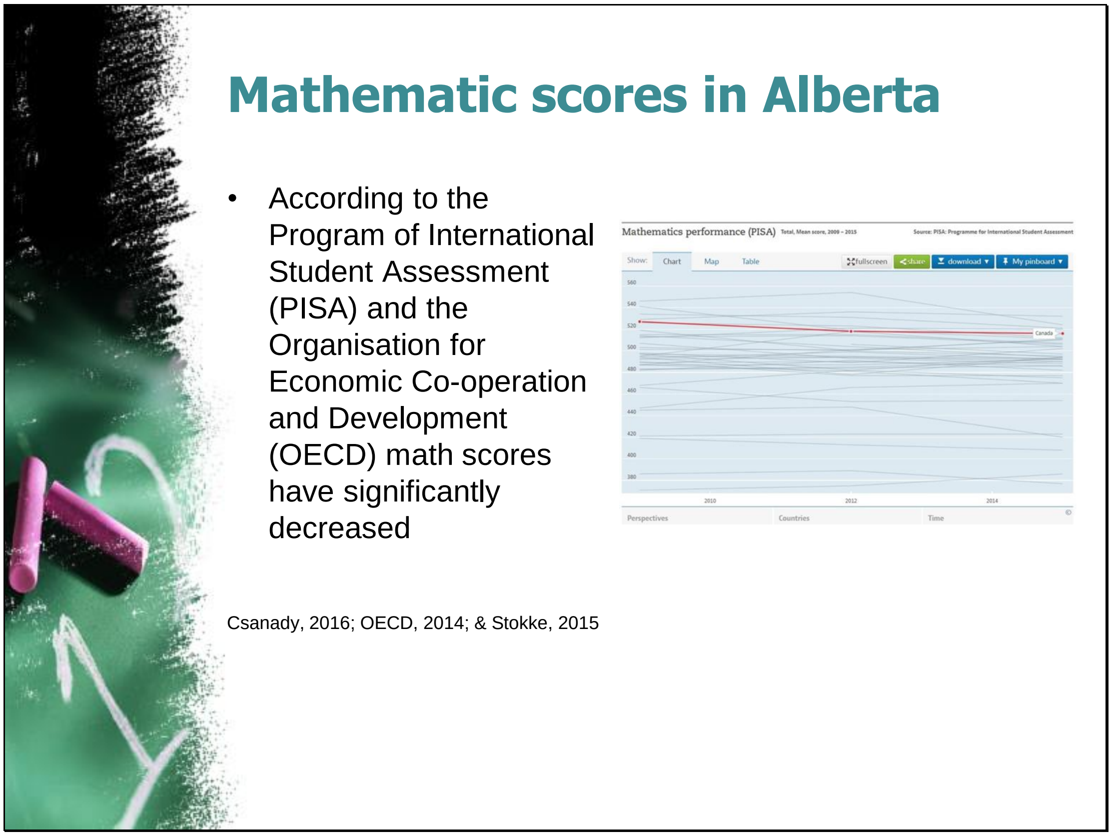


Having knowledge in long term memory is important because it allows the learner to quickly recall the needed information or skill for a particular problem and get back to solving the problem. If knowledge is not available in long term memory then it becomes the job of working memory to find the appropriate data or skill needed to problem solve. This leaves the student cognitively unable to learn new material because working memory is needed for learning but it is too busy trying to fill in gaps that constructivist instruction creates (Kirschner et al., 2006; Paas, Renkl, & Sweller, 2003, 2004).

If a student's long term memory possessed the needed knowledge, that would have been learned prior to a problem solving scenario, the limits of working memory and cognitive load become less of an issue (Kirschner et al., 2006). However, with what Sweller (1988) and Sweller, Ayres, and Kalyuga (2011) said about the processing power needed to approach unfamiliar questions or scenarios after the whole process of trying to figure out which strategy to use, which skills must be learned and in what order they should be used, and finally to carry out some sort of procedure to come up with an answer there will not be a lot of processing capacity left for true learning if the learner does not lessen the burden of a heavy cognitive load.

If long term memory possessed the needed knowledge, that would have been learned prior to a problem solving scenario, the limits of working memory and cognitive load become less of an issue (Kirschner et al., 2006).

Slide 13



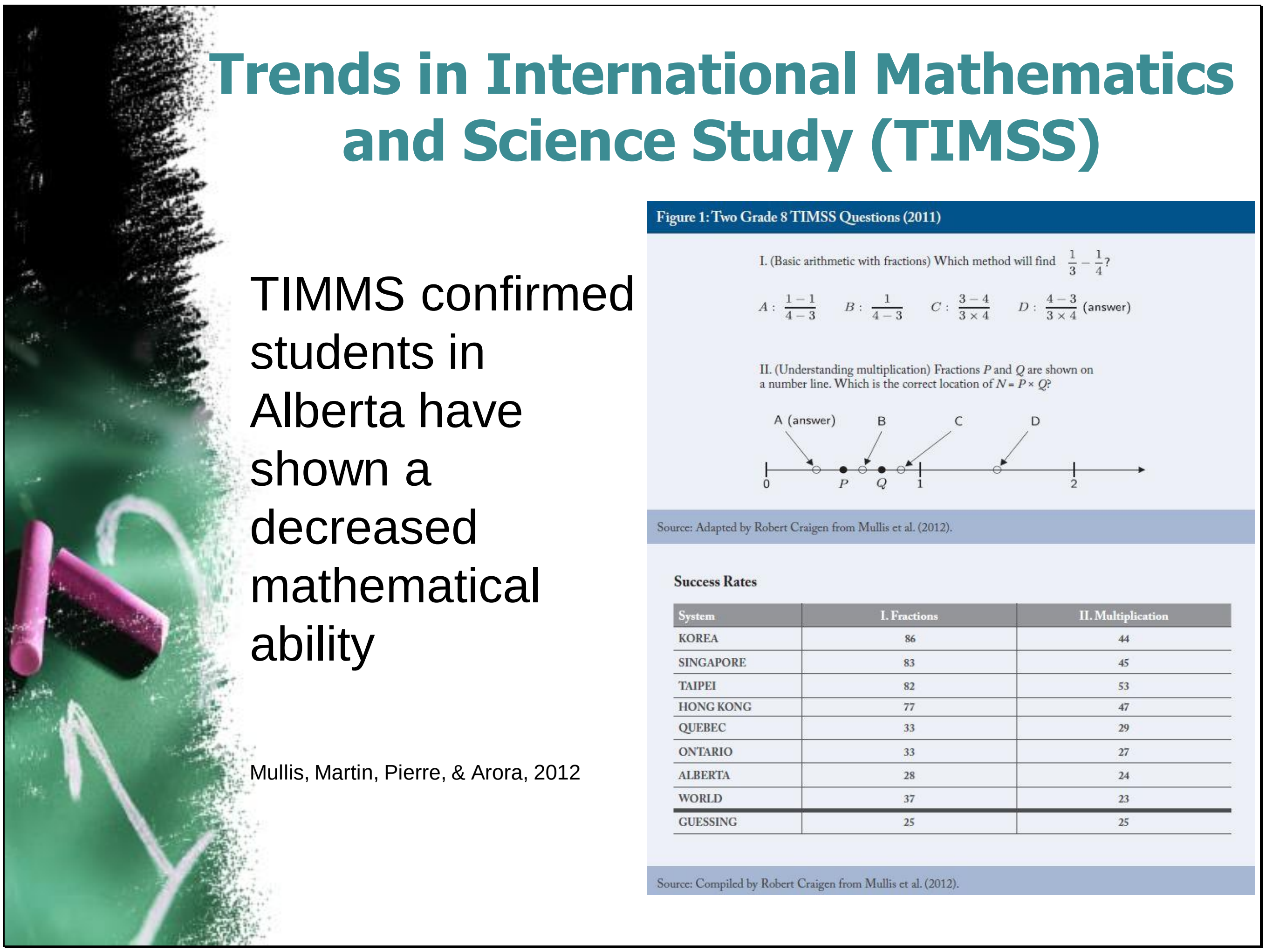
In recent years, use of discovery learning, also known as inquiry or experiential learning, has coincided with a decrease in math competency and performance (Csanady, 2016).

Program of International Student Assessment (PISA) assessed mathematics as a major domain in 2003 to assess student ability and compared these results from the baseline year of 2003 to the most recent year of testing, 2012. PISA scores have been steadily decreasing for about a decade (see figure 1-PISA scores in Canada) which is similar in timing to when discovery learning was implemented as the main mathematics instructional method in Alberta.

According to the results Alberta math scores decreased 32 points between 2003-2012 (OECD, 2014). To put that in perspective in terms of schooling, 41 points corresponds to the equivalent of one full year of education so a decrease of 32 points clearly indicates that there has been a significant decrease in math literacy and ability.

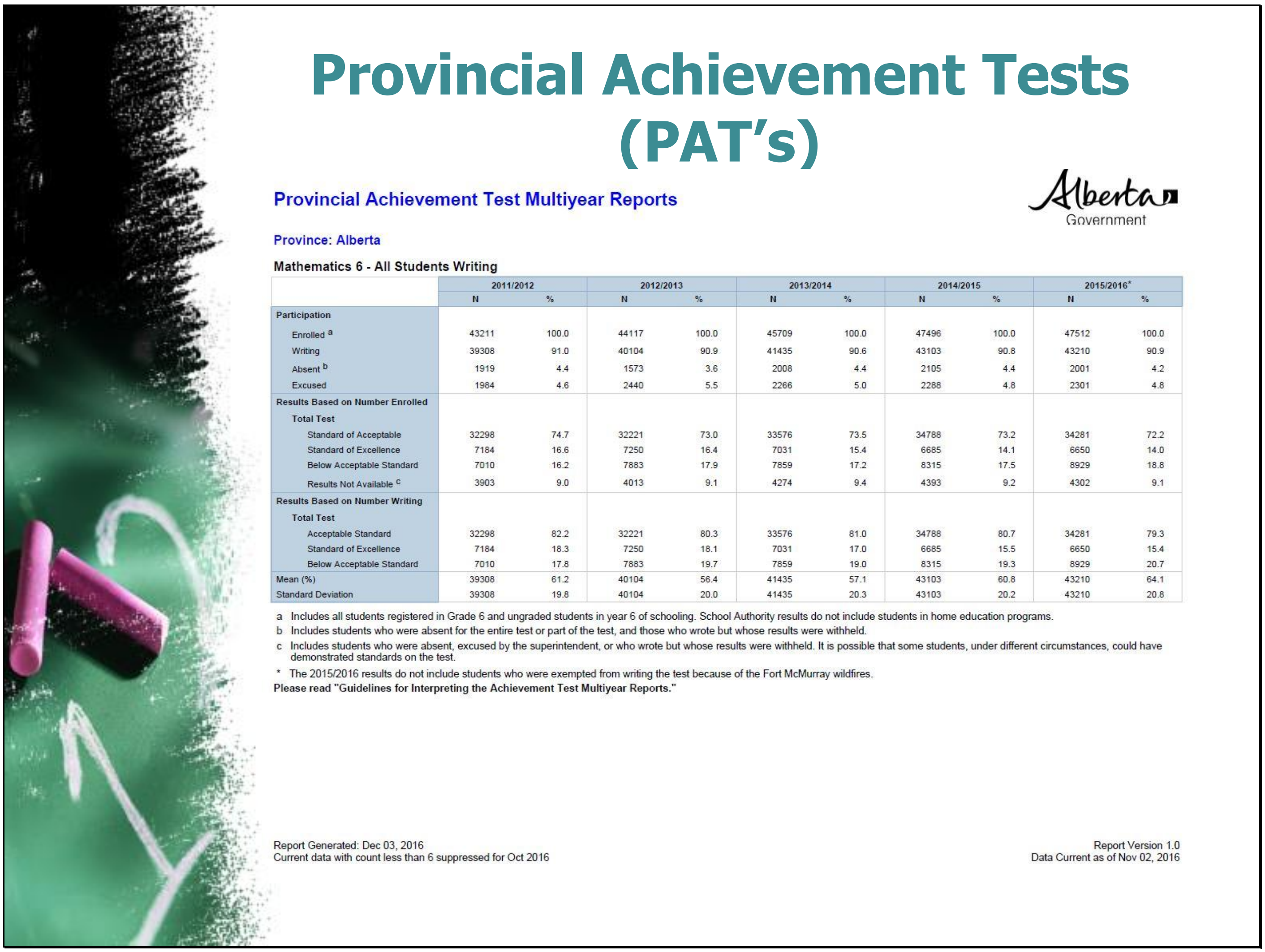
The levels of ability for PISA range from 1 being the lowest, very poor math ability, to 6, very competent at solving complex problems (OECD, 2014; Stokke, 2015). The results of the last PISA indicated that students in Alberta at level 2 doubled while those at level five halved.

Slide 14



TIMSS assesses specific math skills such as fractions or algebra and has recently discovered that students from Alberta have decreased 26 points indicating a significant decrease in mathematical ability. For example, Alberta students now rank near the bottom in regards to performance with fractions, specifically basic skills needed to work with them or multiply them, as can be seen in the figure.

Slide 15



Provincial Achievement Tests (PAT's)

Provincial Achievement Test Multiyear Reports

Alberta Government

Province: Alberta

Mathematics 6 - All Students Writing

	2011/2012		2012/2013		2013/2014		2014/2015		2015/2016*	
	N	%	N	%	N	%	N	%	N	%
Participation										
Enrolled [a]	43211	100.0	44117	100.0	45709	100.0	47496	100.0	47512	100.0
Writing	39308	91.0	40104	90.9	41435	90.6	43103	90.8	43210	90.9
Absent [b]	1919	4.4	1573	3.6	2008	4.4	2105	4.4	2001	4.2
Excused	1984	4.6	2440	5.5	2266	5.0	2288	4.8	2301	4.8
Results Based on Number Enrolled										
Total Test										
Standard of Acceptable	32298	74.7	32221	73.0	33576	73.5	34788	73.2	34281	72.2
Standard of Excellence	7184	16.6	7250	16.4	7031	15.4	6685	14.1	6650	14.0
Below Acceptable Standard	7010	16.2	7883	17.9	7859	17.2	8315	17.5	8929	18.8
Results Not Available [c]	3903	9.0	4013	9.1	4274	9.4	4393	9.2	4302	9.1
Results Based on Number Writing										
Total Test										
Acceptable Standard	32298	82.2	32221	80.3	33576	81.0	34788	80.7	34281	79.3
Standard of Excellence	7184	18.3	7250	18.1	7031	17.0	6685	15.5	6650	15.4
Below Acceptable Standard	7010	17.8	7883	19.7	7859	19.0	8315	19.3	8929	20.7
Mean (%)	39308	61.2	40104	56.4	41435	57.1	43103	60.8	43210	64.1
Standard Deviation	39308	19.8	40104	20.0	41435	20.3	43103	20.2	43210	20.8

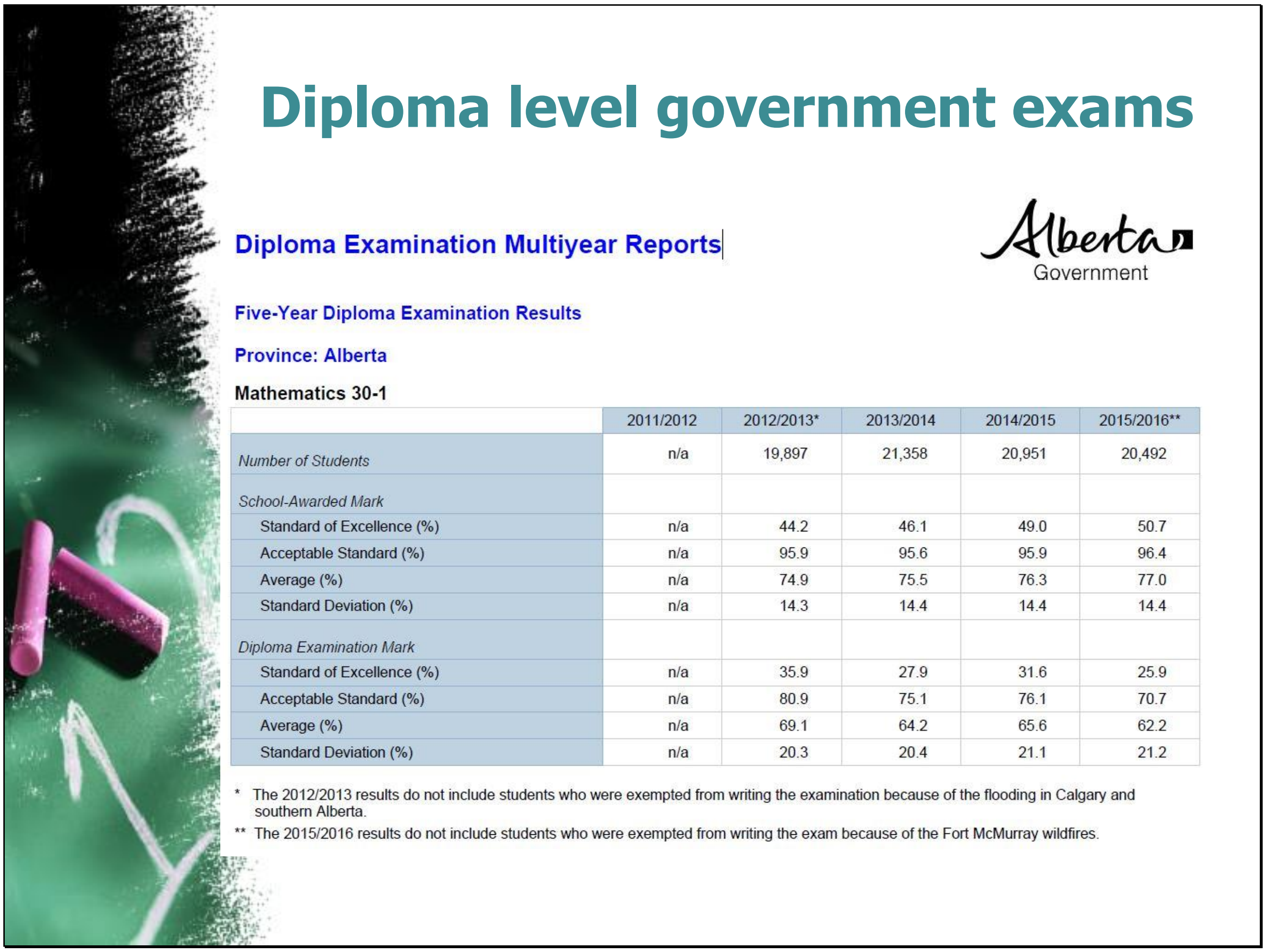
a Includes all students registered in Grade 6 and ungraded students in year 6 of schooling. School Authority results do not include students in home education programs.
b Includes students who were absent for the entire test or part of the test, and those who wrote but whose results were withheld.
c Includes students who were absent, excused by the superintendent, or who wrote but whose results were withheld. It is possible that some students, under different circumstances, could have demonstrated standards on the test.
* The 2015/2016 results do not include students who were exempted from writing the test because of the Fort McMurray wildfires.
Please read "Guidelines for Interpreting the Achievement Test Multiyear Reports."

Report Generated: Dec 03, 2016
Current data with count less than 6 suppressed for Oct 2016

Report Version 1.0
Data Current as of Nov 02, 2016

Alberta math scores on Provincial Achievement Tests (PAT'S) have shown a decrease in mathematical achievement for the years 2012-2016 (Alberta, 2016). For example, there has been a decrease in the number of students at the standard of excellence and acceptable levels while there has been an increase in the number of students below acceptable standards-See figure 3.

Slide 16



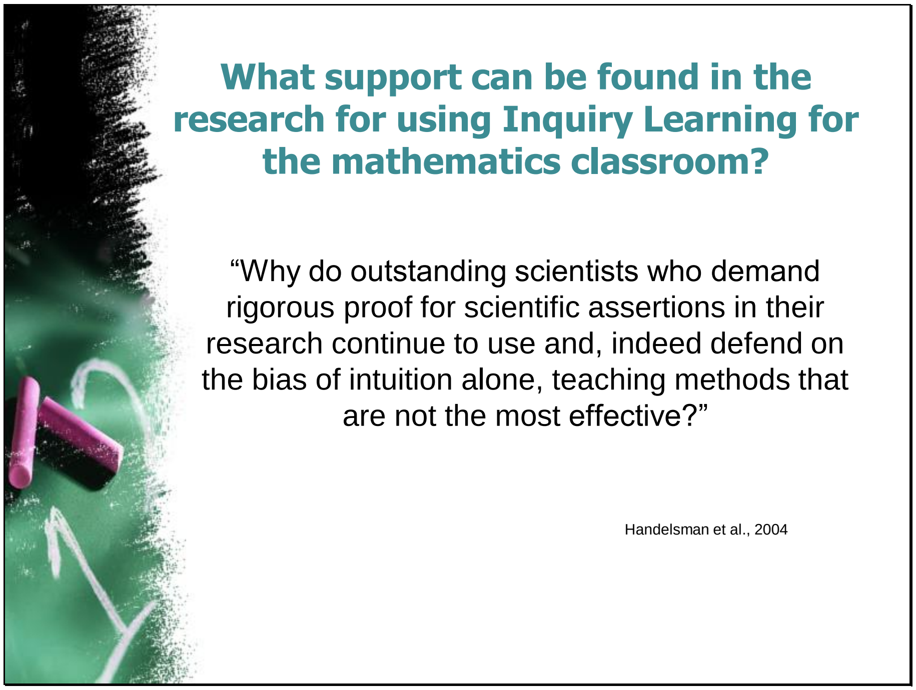
	2011/2012	2012/2013*	2013/2014	2014/2015	2015/2016**
Number of Students	n/a	19,897	21,358	20,951	20,492
School-Awarded Mark					
Standard of Excellence (%)	n/a	44.2	46.1	49.0	50.7
Acceptable Standard (%)	n/a	95.9	95.6	95.9	96.4
Average (%)	n/a	74.9	75.5	76.3	77.0
Standard Deviation (%)	n/a	14.3	14.4	14.4	14.4
Diploma Examination Mark					
Standard of Excellence (%)	n/a	35.9	27.9	31.6	25.9
Acceptable Standard (%)	n/a	80.9	75.1	76.1	70.7
Average (%)	n/a	69.1	64.2	65.6	62.2
Standard Deviation (%)	n/a	20.3	20.4	21.1	21.2

* The 2012/2013 results do not include students who were exempted from writing the examination because of the flooding in Calgary and southern Alberta.

** The 2015/2016 results do not include students who were exempted from writing the exam because of the Fort McMurray wildfires.

There are similar and more pronounced findings for the diploma level government exams at the secondary level (grade 12) (Mark & Mark, 2016), showing a 10% decrease in both the standard of excellence and acceptable standard from 2011-2016 (see figure 4). Middle year (grade 9) students have also failed to meet provincial government targets prompting Albertan's to set new goals for improved numeracy for grades K-12.

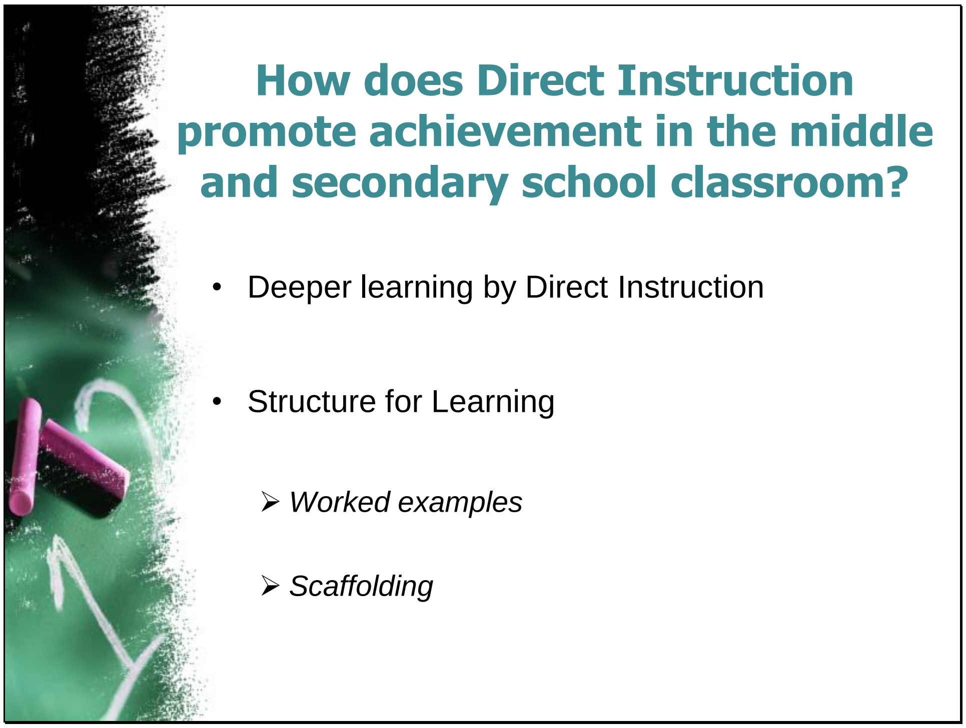
Slide 17



From the literature reviewed the research question, What support can be found in the research for using Inquiry Learning for the mathematics classroom?, has been explored. Inquiry or discovery methods have shown to cause cognitive overload in students leading to erroneous conclusions if left unguided, indicating that strong guidance is necessary for effective learning. There is not enough evidence to support the use of discovery learning in general. To be a useful method of instruction, the method should have positive effects on the learner but through the review of the research this is not the case. An examination of the empirical literature has indicated the opposite to be true, stating discovery learning is not recommended (Duffy & Tobias, 2009; Kirschner et al., 2006). Supporters of inquiry or discovery learning even point out if it is to be used there needs to be some form of direct guidance and some direct teaching of rudimentary foundational skills to process higher order problem solving for complex problems (Bruner 1961; Dewey 1910). Inquiry learning has been used in Alberta recently and has coincided with a drop in mathematical achievement for middle years and secondary level students.

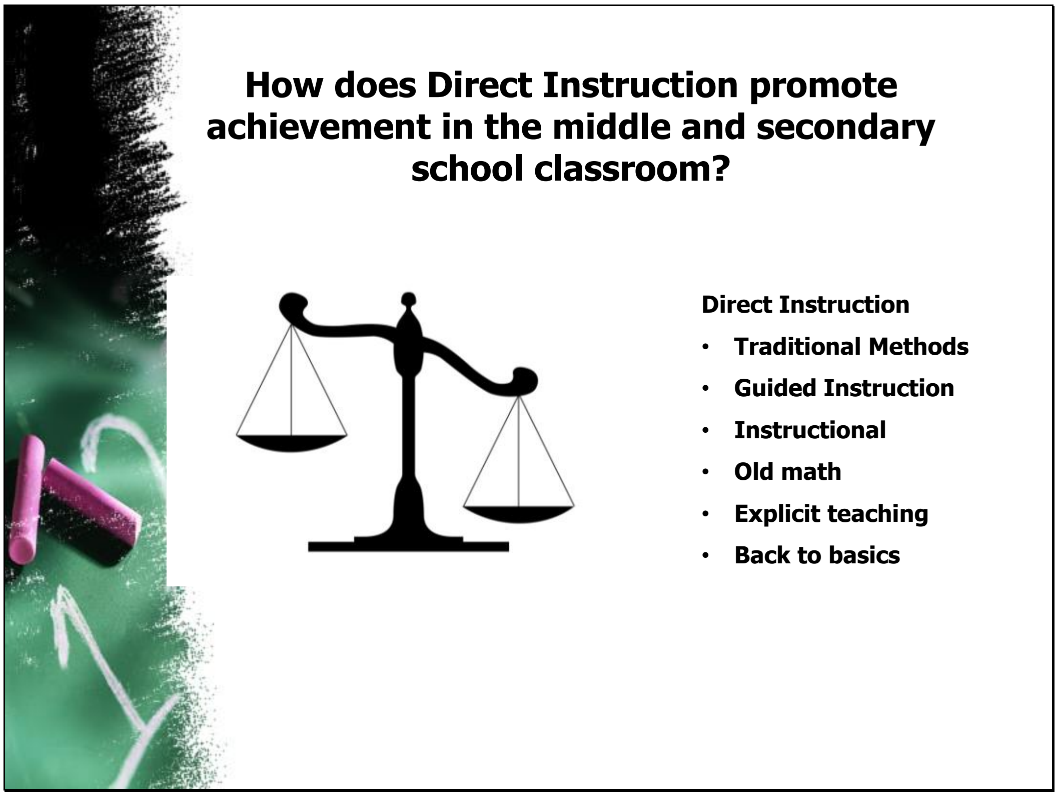
In conclusion, the literature revealed that the arguments for using Inquiry learning in the mathematics classroom do not recommended it due to cognitive overload in the learner, a lack of supporting empirical evidence for discovery learning methods, and the apparent drop in Albertan mathematics scores at various levels during times of inquiry learning being used in the classroom. Handelsman et al. (2004) raise an important question in the realm of science that has direct implications in the mathematics world in regard to teaching method, "Why do outstanding scientists who demand rigorous proof for scientific assertions in their research continue to use and, indeed defend on the bias of intuition alone, teaching methods that are not the most effective?" (p.1).

Slide 18



Key themes regarding how Direct Instruction promotes achievement in the middle and secondary school classroom

Slide 19



There are many terms for Direct instruction, these are just a few that educators use to DI. Knowing the vocabulary will help to understand to which method a key term is referring.

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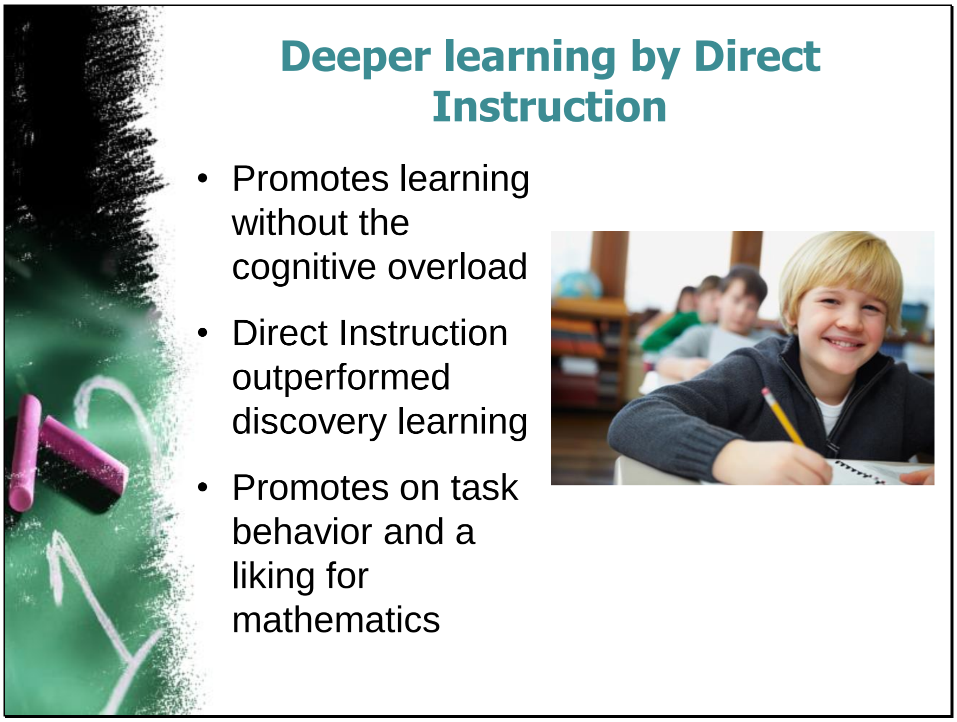

DI supports learners by giving them the tools and strategies they need to learn without causing them cognitive overload (Kirschner et al., 2006). Empirical evidence has documented that via the use of DI, superior results have been achieved with a variety of students such as preschool, elementary, secondary school, and adult students (Adams & Siegfried, 1996; Kim & Axelrod, 2005; Przychodzin, Marchand-martella, Martella, & Azim, 2004). Included in those levels of students who experienced success with DI are regular students, special education students, and non-English speaking students (Adams & Siegfried, 1996; Przychodzin, Marchand-martella, Martella, & Azim, 2004).

DI students outperformed students taught with all other teaching models, such as discovery learning, in all subjects (Adams & Siegfried, 1996; Kim & Axelrod, 2005) the research evidence also indicated a strong favoring of direct instruction over discovery based instruction for nurturing understanding, deeper learning and better problem solvers (Moreno, 2004; Stokke, 2015). Furthermore, no other models came close to student achievement for mathematics students taught with DI. Adams and Siegfried (1996) and Flores and Kaylor (2007) noted that students taught with DI preferred DI, were on task a higher percentage of time, showed better scores on comprehensive post-tests of the basics in mathematics, and showed a better attitude towards mathematics overall.

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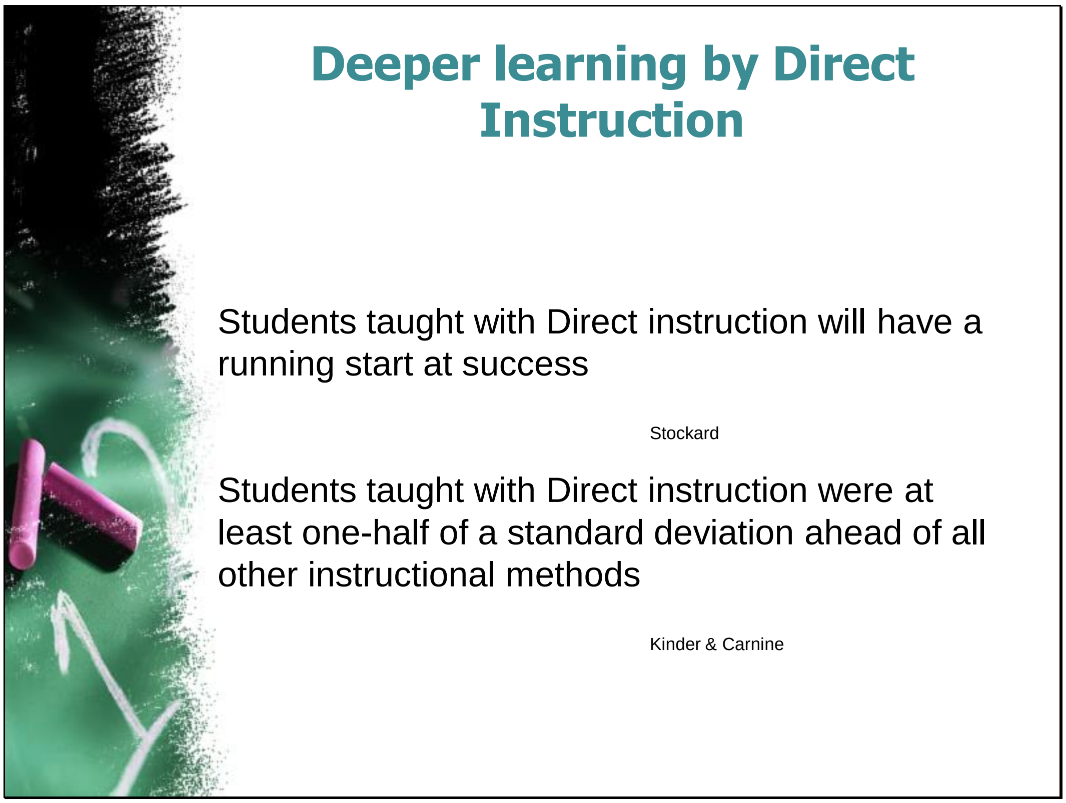

Stockard (2015) points out the importance of starting DI early on in educational years so that the learner benefits from an early age that will build as they continue their studies.
Kinder and Carnine (1991) use empirical evidence to point out that DI promotes higher academic gains than other forms of instruction such as Piagetian approaches, open classroom, parent-education approaches, and discovery learning. Students taught mathematics using DI were at least one-half of a standard deviation ahead of all other instructional methods (Kinder & Carnine, 1991)

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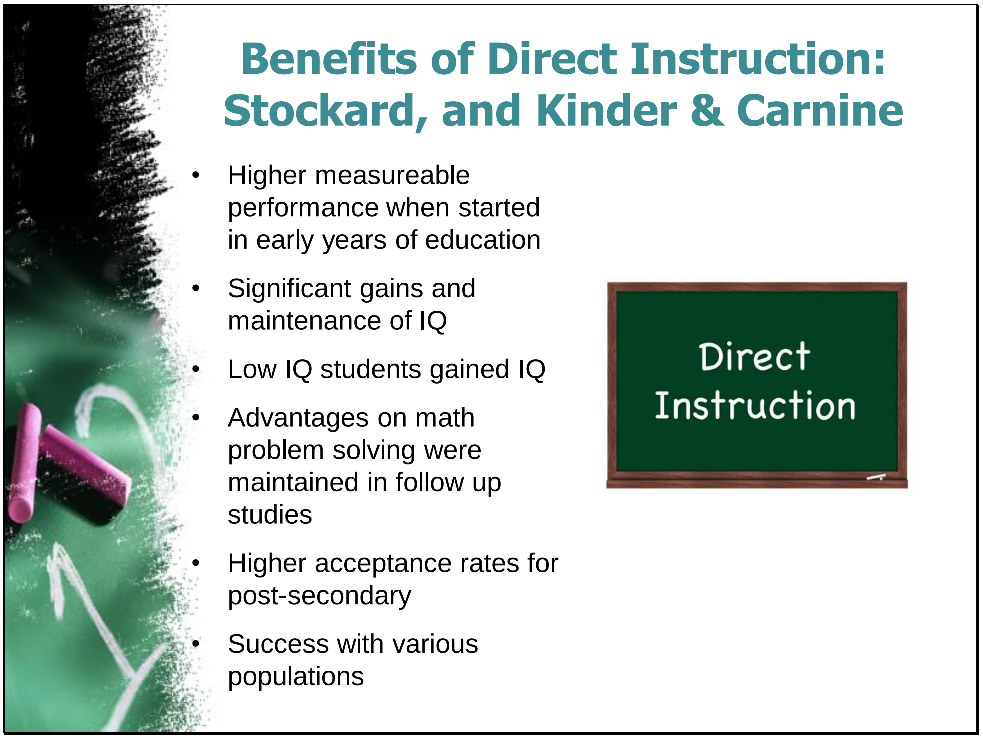

Stockard (2015) and Kinder and Carnine (1991) examined empirical evidence to point out that DI promotes higher academic gains than other forms of instruction such as Piagetian approaches, open classroom, parent-education approaches, and discovery learning. Students taught mathematics using DI learn more while developing positive views of their academic ability, give them a "running start at success" (Stockard, 2015, p.7), and were at least one-half of a standard deviation ahead of all other instructional methods (Kinder & Carnine, 1991). Stockard (2015) and Kinder and Carnine (1991) conclude by stating that DI and DI principles should be used to teach basic and higher order skills and notes that DI is particularly useful in mathematics education and is associated with learner benefits such as 1) higher measurable achievement for students at the end of third grade that started DI in Kindergarten versus students that started it later; 2) significant gains and maintenance of IQ; 3) Low IQ students (under 80) also showed increases in IQ gaining nearly as much each year in reading and math as DI students with higher IQ; 4) follow up studies of fifth and sixth graders who received DI maintained their advantage with the strongest results seen on math-problem solving tests, and thus avoiding the "fourth grade slump" (Stockard, 2015); 5) middle year and secondary students who received DI in primary grades maintained their mathematical advantage over their peers not educated with DI and also had more success with college acceptance rates; 6) DI has proven successful across time, as follow up tests showed; and 7) DI also yielded exemplary results with populations of various demographics such as students from large and middle-sized cities, rural white and rural black communities, and Hispanic and Native American communities.

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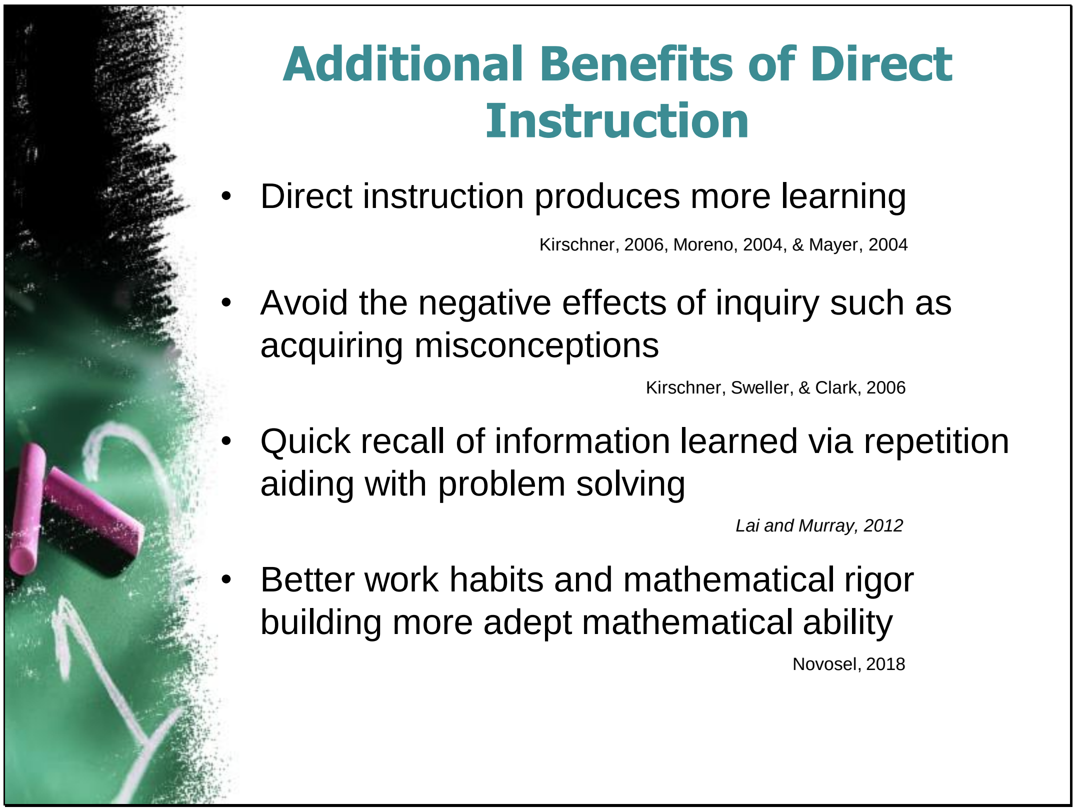

According to Lai and Murray's research, being able to recall knowledge quickly that has been practiced many times helps ease the burden of recall and helps the learner toward a route of understanding. Repetition is therefore a powerful tool to help students deepen and develop their understanding (Lai & Murray, 2012; Novosel, 2018). Memorising, repetition, and understanding are linked together, and together help the learner develop a deeper level of understanding (Lai & Murray, 2012). Novosel (2018) adds to this by noting that students taught with DI tend to display better work habits and demonstrate mathematical rigor. Novosel (2018) says that due to discovery learning being the method of instruction presently in Alberta, the students have difficulty working on their own and need constant direction. Novosel (2018) offered two reasons for this 1) DI is more effective to promote deeper understanding, as was also previously mentioned by Lai and Murray (2012) and 2) with the present discovery learning model students lack the basics and foundation to allow them to approach problem solving on their own which contributes to a lack of personal confidence or mathematical ability.

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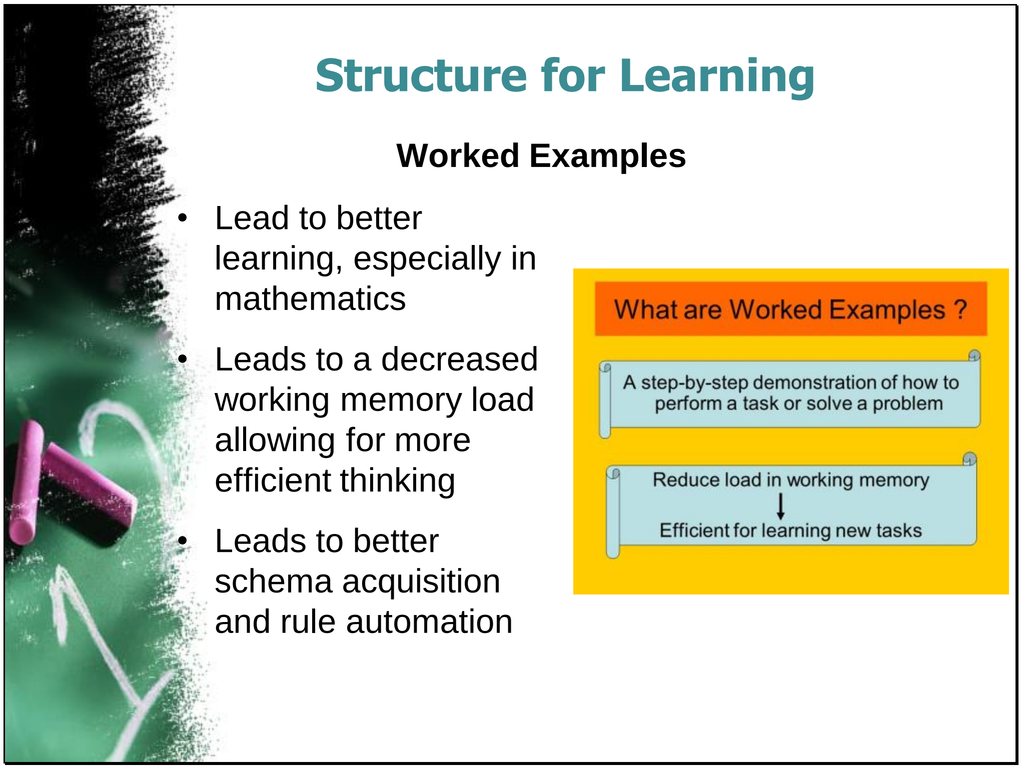

Worked examples are taught with DI methods (Stokke 2015) and are defined as a "step-by-step demonstration of how to perform a task or solve a problem" (Clark, Nguyen, & Sweller, 2006, p. 190). Kirschner (2006), Sweller (1988), Sweller, Ayres, and Kalyuga (2011), and Mayer (2004) noted that use of worked examples led to better learning, especially in mathematics. For example, students who studied algebra using worked examples learned more by studying worked examples than by solving equivalent problems.

Sweller (1988) and Sweller, Ayres, & Kalyuga (2011) attributes learner success using worked examples to a decreased working memory load because the need to search for strategies is minimized and allows for freer progress from move to move.

Research has shown that a three year math program has been successfully and effectively completed in two years using by directly instructing worked examples (Ward & Sweller, 1990). Ward and Sweller (1990) and Sweller, Ayres, and Kalyuga (2011) attribute this success to the schema acquisition and rule automation that come with studying worked examples. Ward and Sweller (1990) added to this by saying that worked examples focus attention on "problem solving states and their associated moves" (p. 36) allowing for more efficient learning, and

Sweller, Ayres, and Kalyuga (2011) said "that learners have a decided advantage in studying worked examples" (p. 108) as they decrease the learners overall cognitive load.

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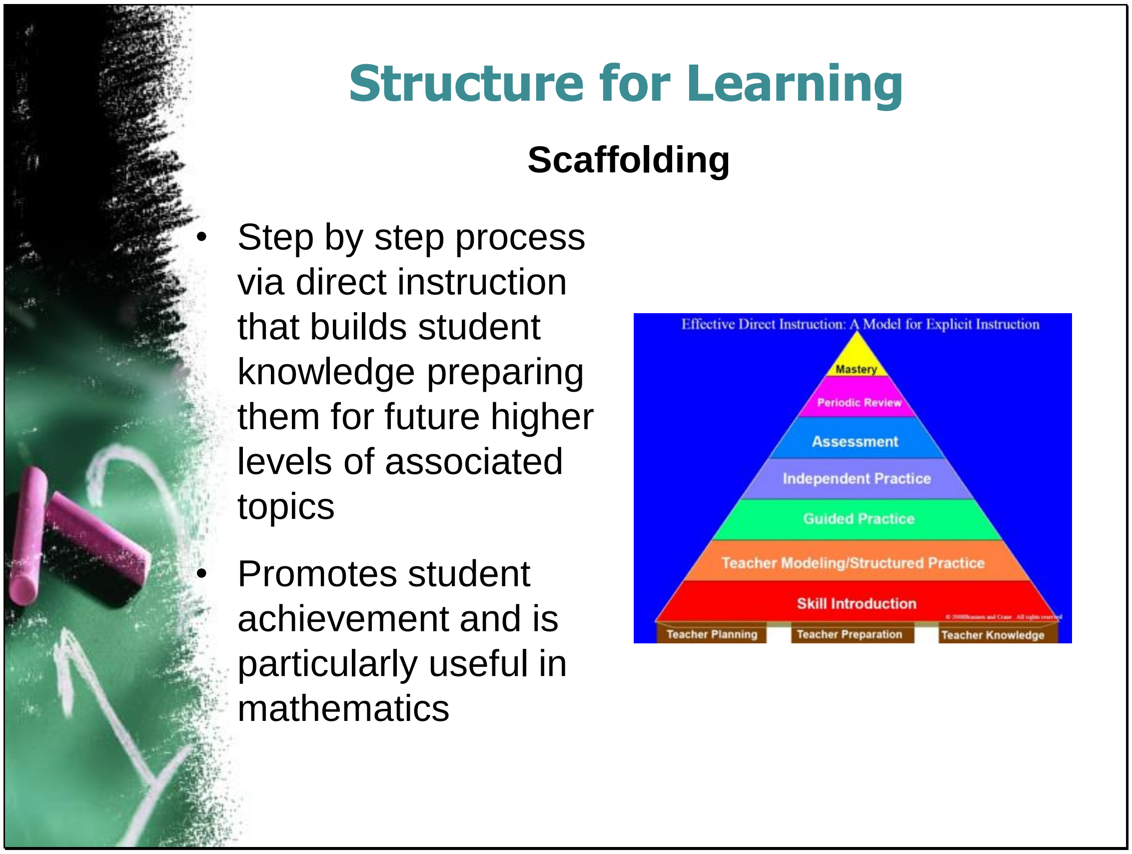

Scaffolding is known as the process that enables the learner to solve a problem, complete a task, and achieve a goal that would have otherwise been difficult for the learner to attain if left unassisted (Bakker, Smit, & Wegerif, 2015). Scaffolding is a step-by-step procedure that builds student skills needed to work with future higher levels of associated topics. DI makes use of scaffolding so there is a clear process of skill introduction, modelling the skill, guided practice, independent practice, assessment, review, and mastery (Crane, & Brannen, 2008) to see if all concepts have been grasped and correct lines of work are proceeding to advance towards a correct solution.

According to Bakker, using scaffolding in an educational setting, the instructor adapts their lesson to support the student, followed by a gradual withdrawal (fade) of support in hopes that the transfer of responsibility to the students occurs and the student is able to take responsibility. In other words, the teacher adapts their lesson, through DI guides the learner, then assesses the student either formatively or summatively to see if the material is retained, understood, and ready to be applied. Bakker also notes that scaffolding promotes student achievement and is particularly useful in mathematics.

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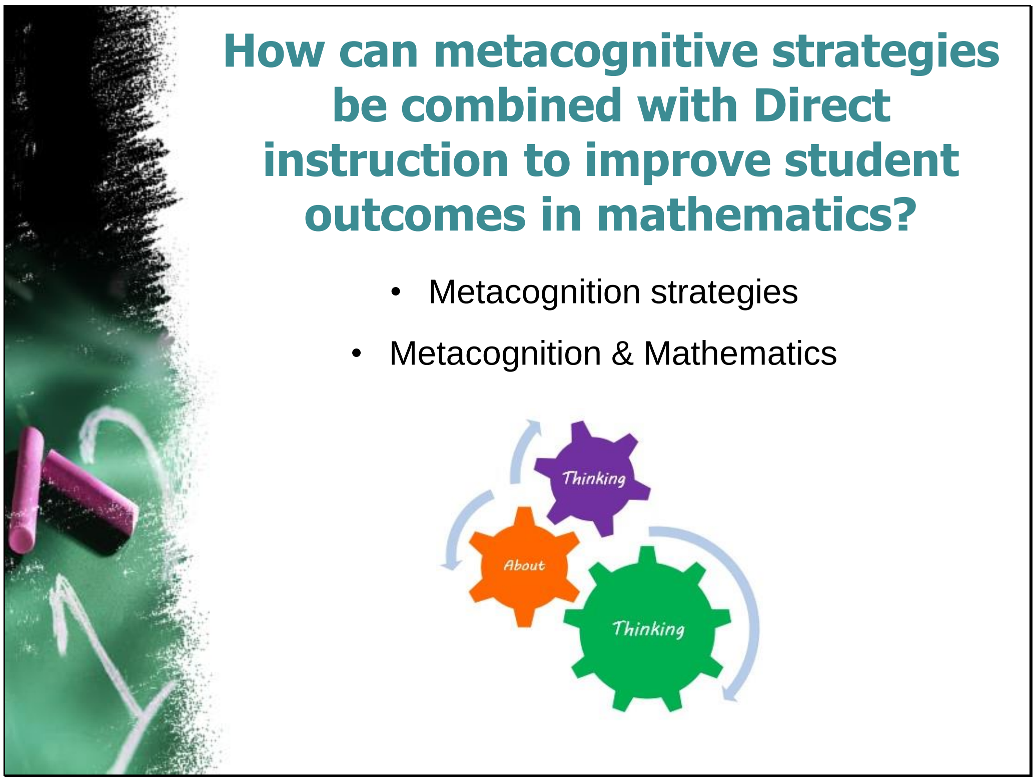

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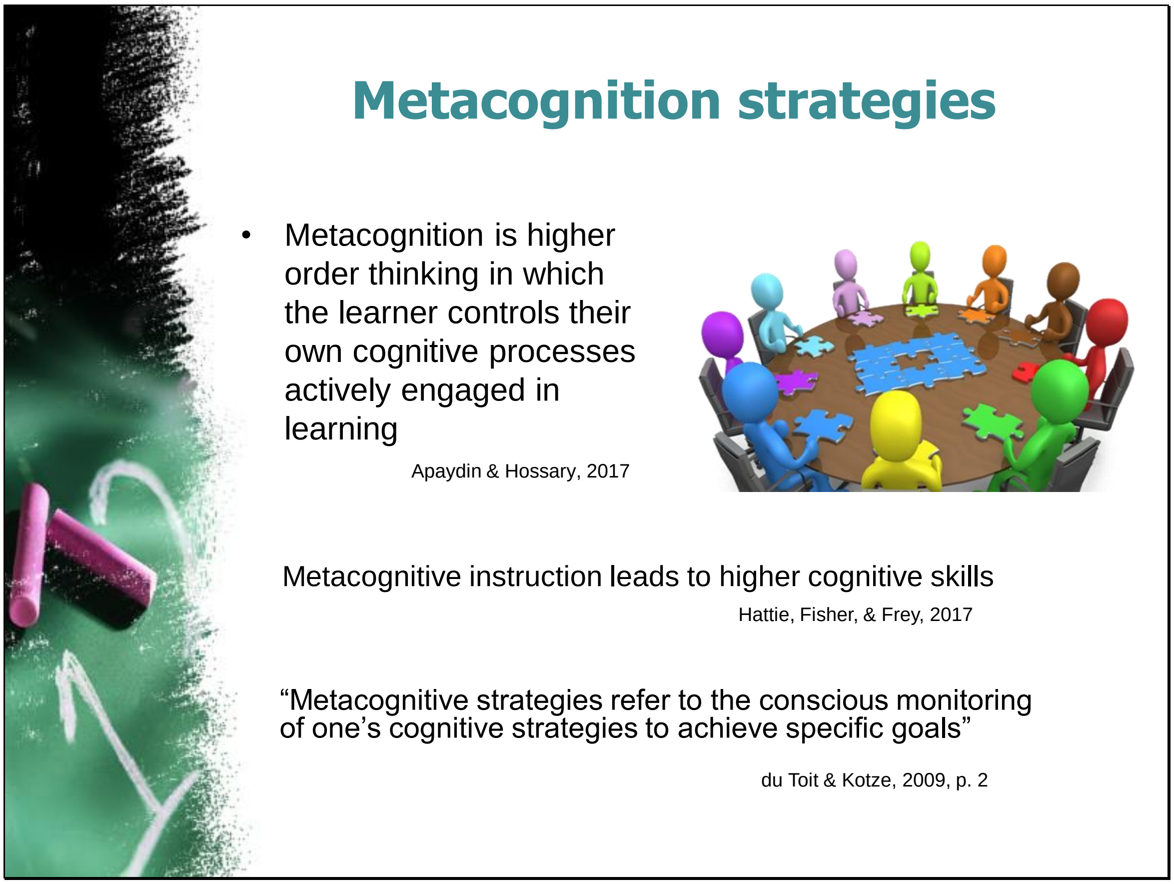

The reviewed literature supports the use of metacognition along with DI to improve student success in mathematics (Apaydin & Hossary, 2017; Behzadi, Hosseinzadeh Lotfi, & Mahboudi, 2014; Farina, Weinberg, & Commitante, 2015; Hattie, Fisher, & Frey, 2017; Heemsoth & Heinze, 2016; Stokke 2015; van Velzen, 2016).

In general metacognition is higher order thinking in which the learner controls their own cognitive processes actively engaged in learning (Apaydin & Hossary, 2017). Metacognition is the process of thinking about your own thinking and research has shown that students who underwent metacognitive instruction exhibit higher cognitive skills than those who were not instructed about their own metacognition (Hattie, Fisher, & Frey, 2017).

“Metacognitive strategies refer to the conscious monitoring of one’s cognitive strategies to achieve specific goals” (du Toit & Kotze, 2009, p. 2).

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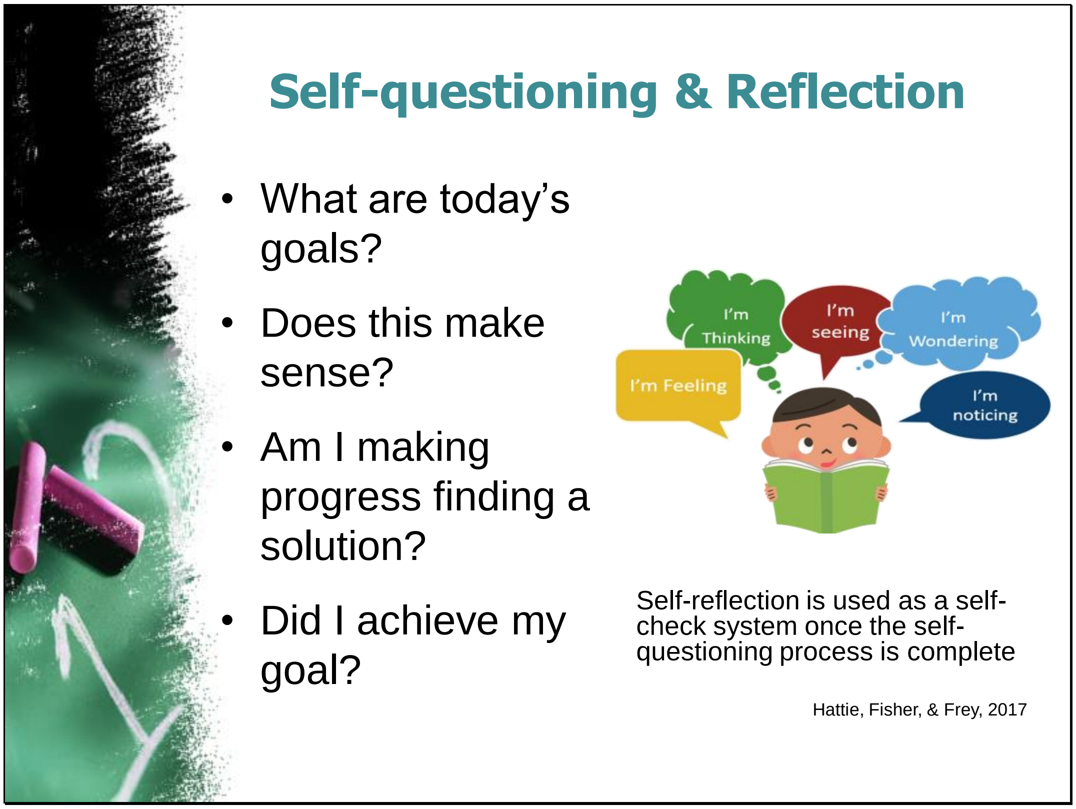

Self-questioning is a process in which the learner thinks about their thinking by asking themselves questions as they move through the problem-solving process using question like "Does this make sense?" "Am I making progress finding a solution?" (Hattie, Fisher, & Frey, 2017, p. 185). Hattie proposes that to work through mathematical tasks the learner uses the self-questioning process to ensure metacognition development and successful completion of the problem-solving process. Hattie, Fisher, and Frey (2017) added to this that pre and post-lesson questions will help the learner develop their metacognition which again in turn aids their mathematical learning process. For the pre-lesson questions he suggests "What are today's goals?" "How much do I already know about today's goals? and for the post-lesson questions he suggests What was today's goals? Did I achieve this goal?" (Hattie, Fisher, & Frey, 2017, p.186).

By encouraging this type of process learners are encouraged to develop unpacking strategies that they can actively use and purposefully contemplate. Hattie suggests self-reflection as a process to act as a self-check system once the self-questioning process is complete. This is effective because it serves to assess what the learner has actively processed metacognitively and what they have truly learned. The process of self-reflection helps the learner understand where they were and where they are now so that they have a method of thinking about what they think about during the problem-solving process.

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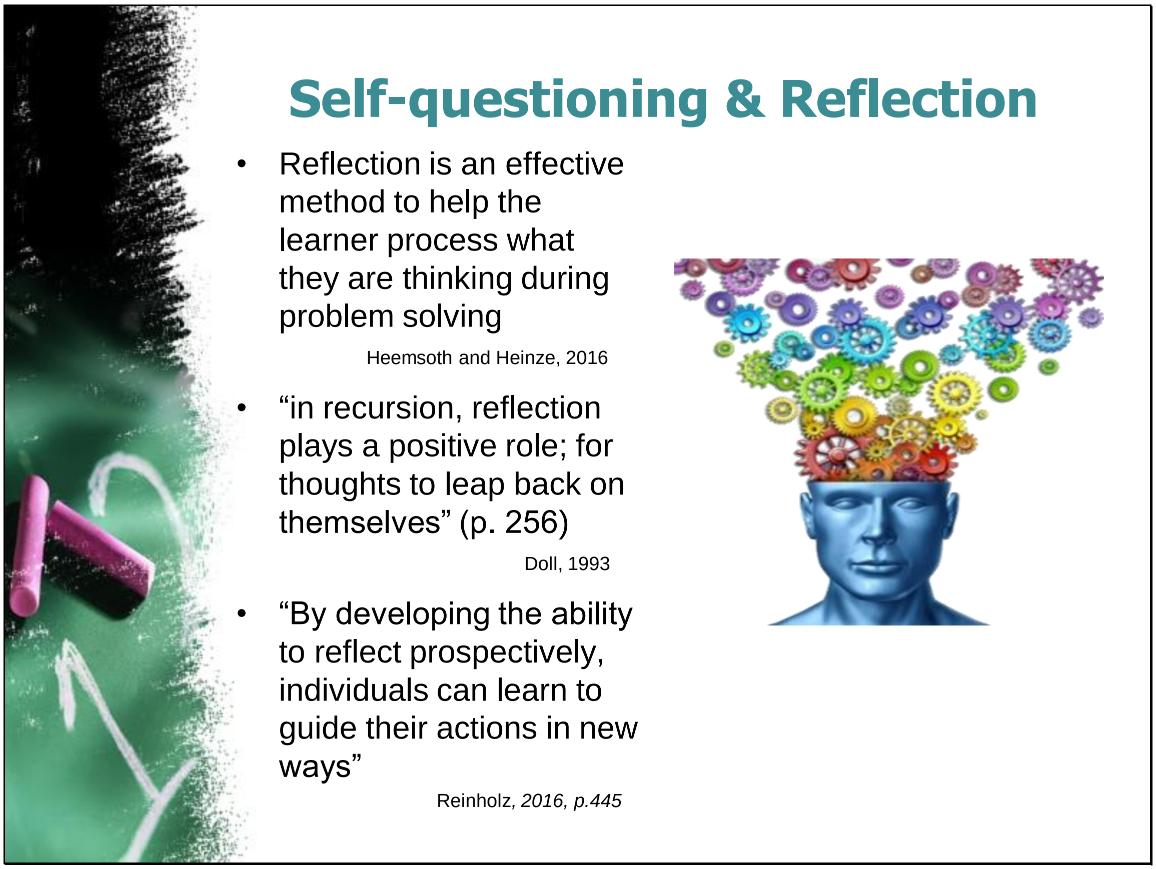

Heemsoth and Heinze (2016) agree that the process of reflection is an effective method to help the learner process what they are thinking during problem solving. Heemsoth and Heinze (2016) confirmed the importance of self-reflection and its application by assessing the ability of grade seven and eight students to work with fractions. Their research supports the notion that reflection on errors will enable a student to think deeper and in more detail. They noted students that reflected on their own errors (error-centered condition) versus students that were just shown the correct answers to study (solution-centered condition), experienced more effective learning and better knowledge acquisition. This increased ability lead to a significant increase in grades and overall performance and satisfaction in mathematics.

Doll (1993), Lewis (2004), and Luo (2004) also saw the value in reflection by expressing their beliefs in the value of the 4R's; Richness, Recursion, Relations, and Rigor. The second R, recursion, is related to reflection. Recursion is the idea of analyzing phenomena, formulating thought about it, reflecting on that thought, analyze again, formulate another deeper thought, and reflect on it once more (Doll, 1993; Luo, 2004). Doll (1993) says, "in recursion, reflection plays a positive role; for thoughts to leap back on themselves" (p. 256) and continuing these processes is what leads to higher level thinking, also known as critical thinking, by the learner. Luo (2004) also points out the importance of thoughts leaping back on themselves so that the learner can develop competence in the form of organized thought allowing the learner "to figure out patterns and to jump to a higher level of learning" (p. 9). Lewis (2004) backs up the importance of reflection when she discussed how recursion in the form of metacognition was used to help the students reflect about topics of study to broaden and deepen their daily oral language to be applied in new situations and adapted as necessary. By using this continuous process Doll (1993), Lewis (2004), and Luo (2004) are pointing out that in curriculum filled with recursion there is no beginning and no end and that students should be encouraged to continue this process to transform the mind. This transformation will enrich the learners' experience in a variety of settings so that they can so that they can make use of their newly learned reflective critical thinking ability.

Reinholz (2016) also believed in a recursion like cyclical process of reflection where one type of reflection is the beginning of the process, prospective, and the other the end, retrospective. Reinholz (2016) discussed the prospective reflection as the type that guides the learner's actions during a learning experience and the retrospective reflection as one that consolidates what was learned to be used in the next prospective learning phase or new learning experience. Reinholz (2016) notes that prospective reflection is particularly useful in mathematics because it helps the learner notice relevant elements of a problem and act accordingly allowing them to be more engaged within the context of the problem. "By developing the ability to reflect prospectively, individuals can learn to guide their actions in new ways" (Reinholz, 2016, p. 445) during the process of problem solving, and in future problem-solving scenarios. The idea is to have the student learn to reflect retrospectively and prospectively together to help the learner know what to focus on when problem solving. When this happens knowing what to attend to becomes automated, enabling the learner to reflect more efficiently prospectively during a learning experience so they can focus on pertinent details during the learning experience instead of just reflecting on them after the experience has ended. Reinholz (2016) noted that it is the continual use of the combination of retrospective and prospective reflection, that enables the learner to change their prospective reflection in future problem solving scenarios and allows the learner to change what they attend to when problem solving.

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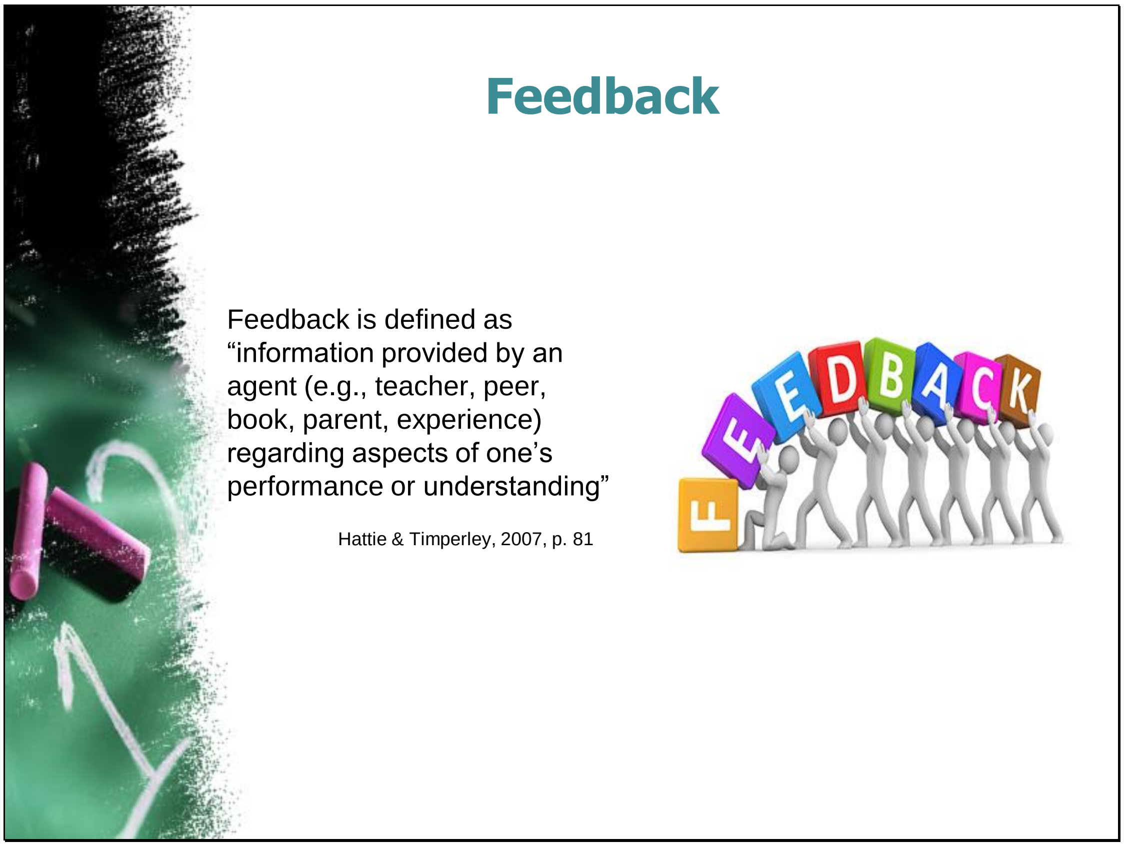

Helping learners improve their metacognitive knowledge and their metacognitive processes is achieved by providing them with feedback (Stokke, 2015). Feedback is defined as “information provided by an agent (e.g., teacher, peer, book, parent, experience) regarding aspects of one’s performance or understanding” (Hattie & Timperley, 2007, p. 81).

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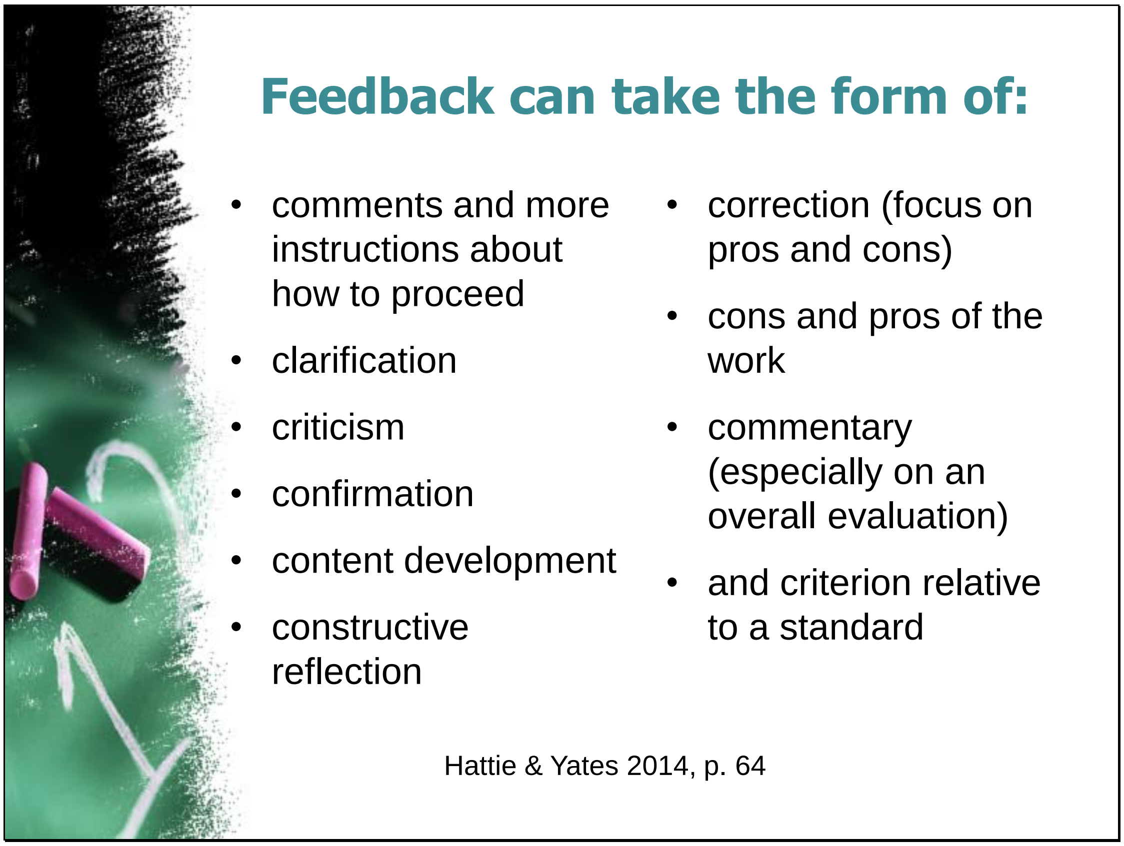

Feedback can take the form of “comments and more instructions about how to proceed, clarification, criticism, confirmation, content development, constructive reflection, correction (focus on pros and cons), cons and pros of the work, commentary (especially on an overall evaluation), and criterion relative to a standard” (Hattie & Yates 2014, p. 64).

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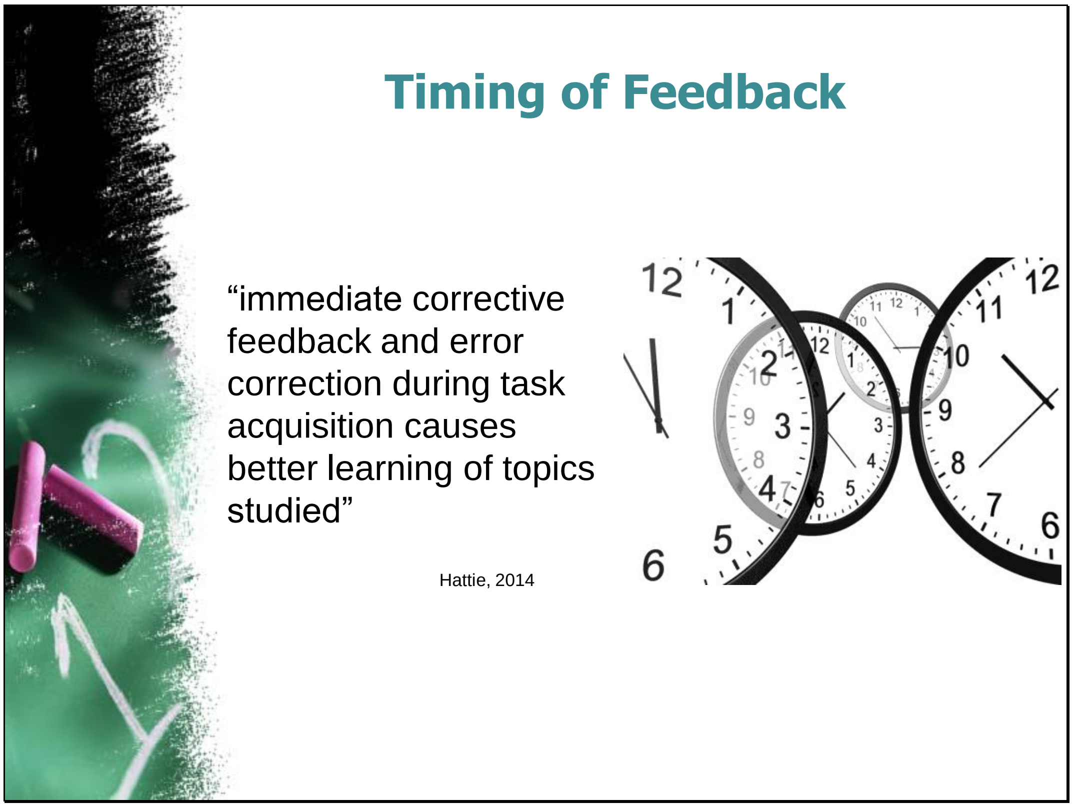

Hattie, Fisher, and Frey (2017) discusses the timing of feedback noting that if dialogic approaches, teaching based on discussion and waiting before giving feedback, were used feedback would not occur immediately but instead more towards the end of a problem-solving exercise as compared to immediately if using more of a direct teaching method. In another paper by Hattie and Yates (2014) he elaborates on this by saying that immediate corrective feedback and error correction during task acquisition causes better learning of topics studied especially at the process level on tasks like classroom activities.

This falls in line with the DI methods and procedures aimed at helping learners of mathematics acquire and accommodate new knowledge and problem-solving procedures. Immediate performance feedback has shown to improve student knowledge acquisition (Kollöffel & de Jong, 2016). Kollöffel and de Jong (2016) studied the effect of immediate social comparison feedback and discovered that having feedback, during instruction, contributed to significant learning gains on pre and post-test scores. This type of approach is also supported by advocates of DI methods to ensure smooth transition of learning to minimize learning erroneous problem-solving strategies (Kirschner, 2006).

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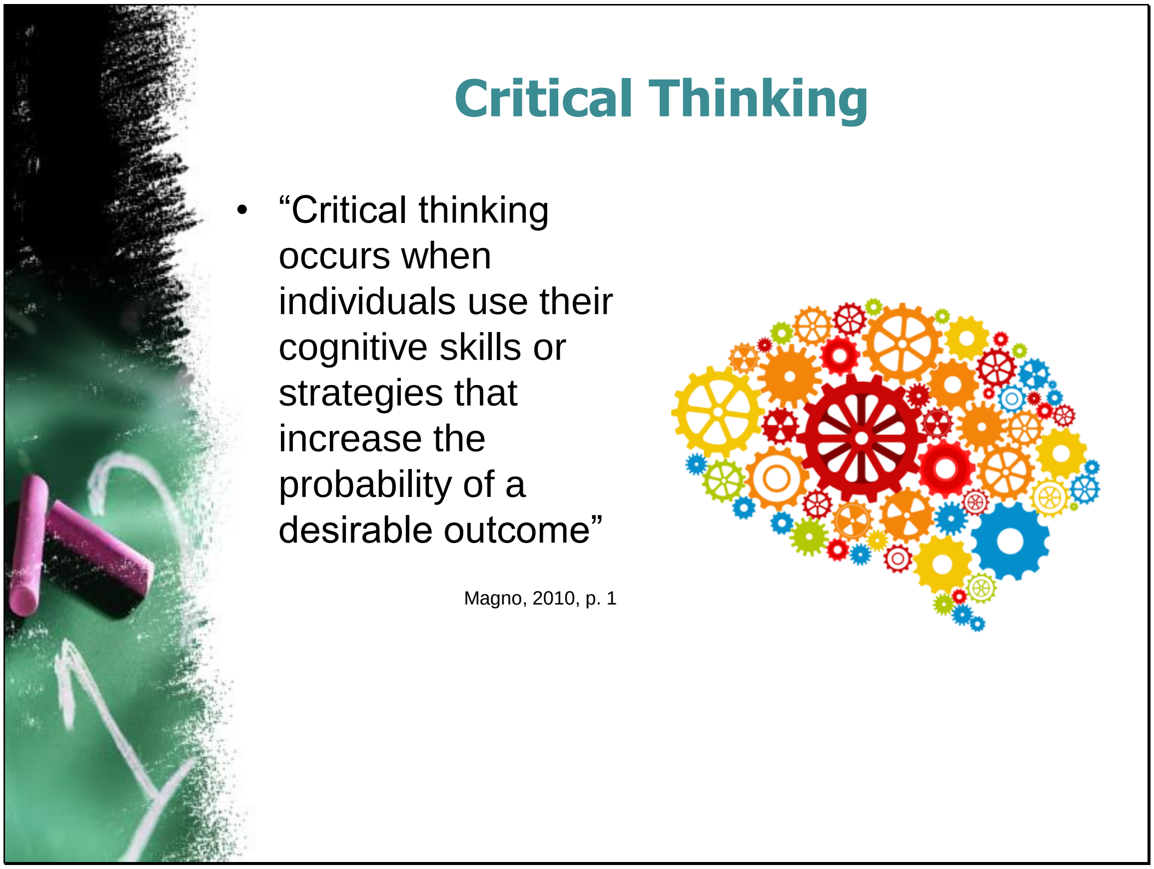

Metacognitive skills previously mentioned help the learner build their critical thinking capacity (Magno, 2010), which leads to better problem solving ability. Critical thinking is the objective analysis and evaluation of a situation to come to a conclusion about a scenario observed or experienced. "Critical thinking occurs when individuals use their cognitive skills or strategies that increase the probability of a desirable outcome" (Magno, 2010, p. 1). By making use of metacognitive skills to develop critical thinking ability the learner activates many metacognitive skills, such as self-monitoring, reflection, and various forms of knowledge, to achieve higher order thinking (critical thinking) in order to solve a problem.

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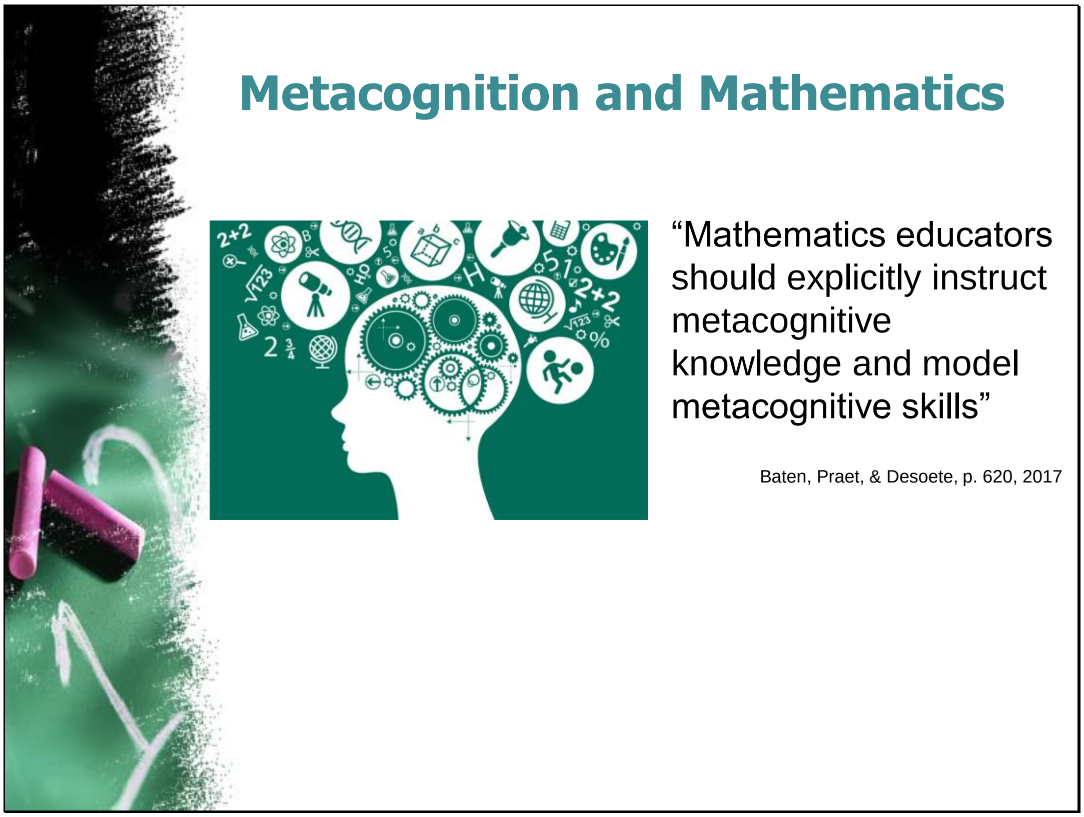

Since metacognition does not automatically develop in the learner, educators play a key role in the education of metacognition to students to encourage development (Baten, Praet, & Desoete, 2017). “Mathematics educators should explicitly instruct metacognitive knowledge and model metacognitive skills” (Baten, Praet, & Desoete, 2017, p.620) to the learner to maximize mathematical achievement. Baten et al. (2017) suggest using DI as well as a variety of other methods such as reflective journal writing, strategic questions, and reflection questions to metacognitively train secondary school students. Baten et al. (2017) also suggest starting metacognitive education in kindergarten to minimize the gap between students who have differing levels of exposure to metacognitive strategies in hopes that metacognitive knowledge will be better in later years of their education, which leads to better mathematical achievement.

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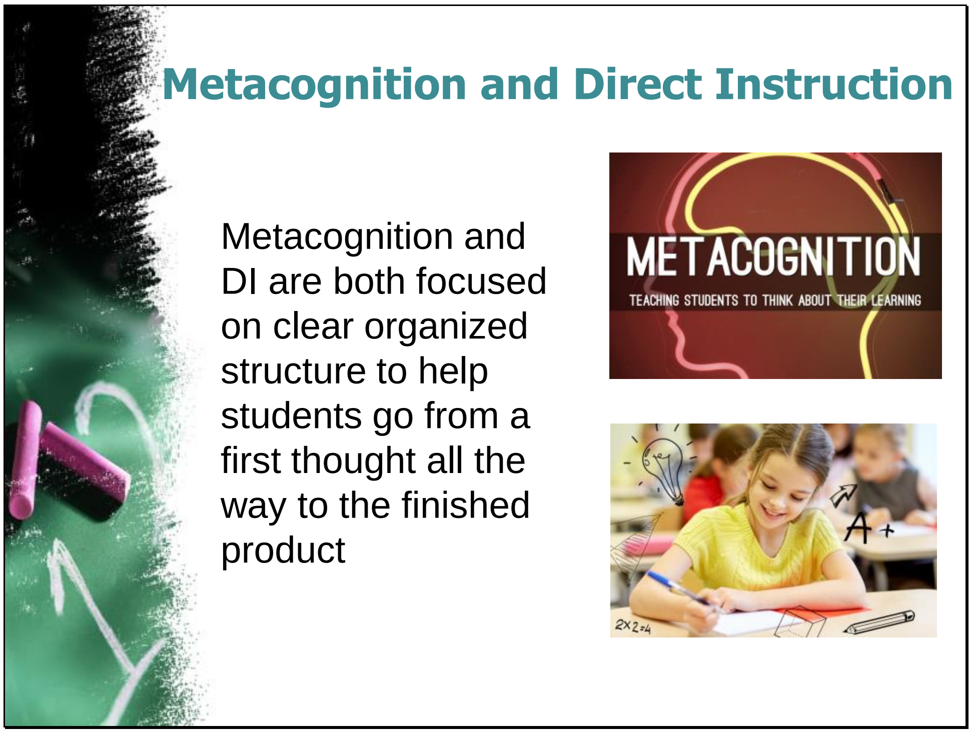

Metacognition and DI are both focused on clear organized structure to help students go from a first thought all the way to the finished product.

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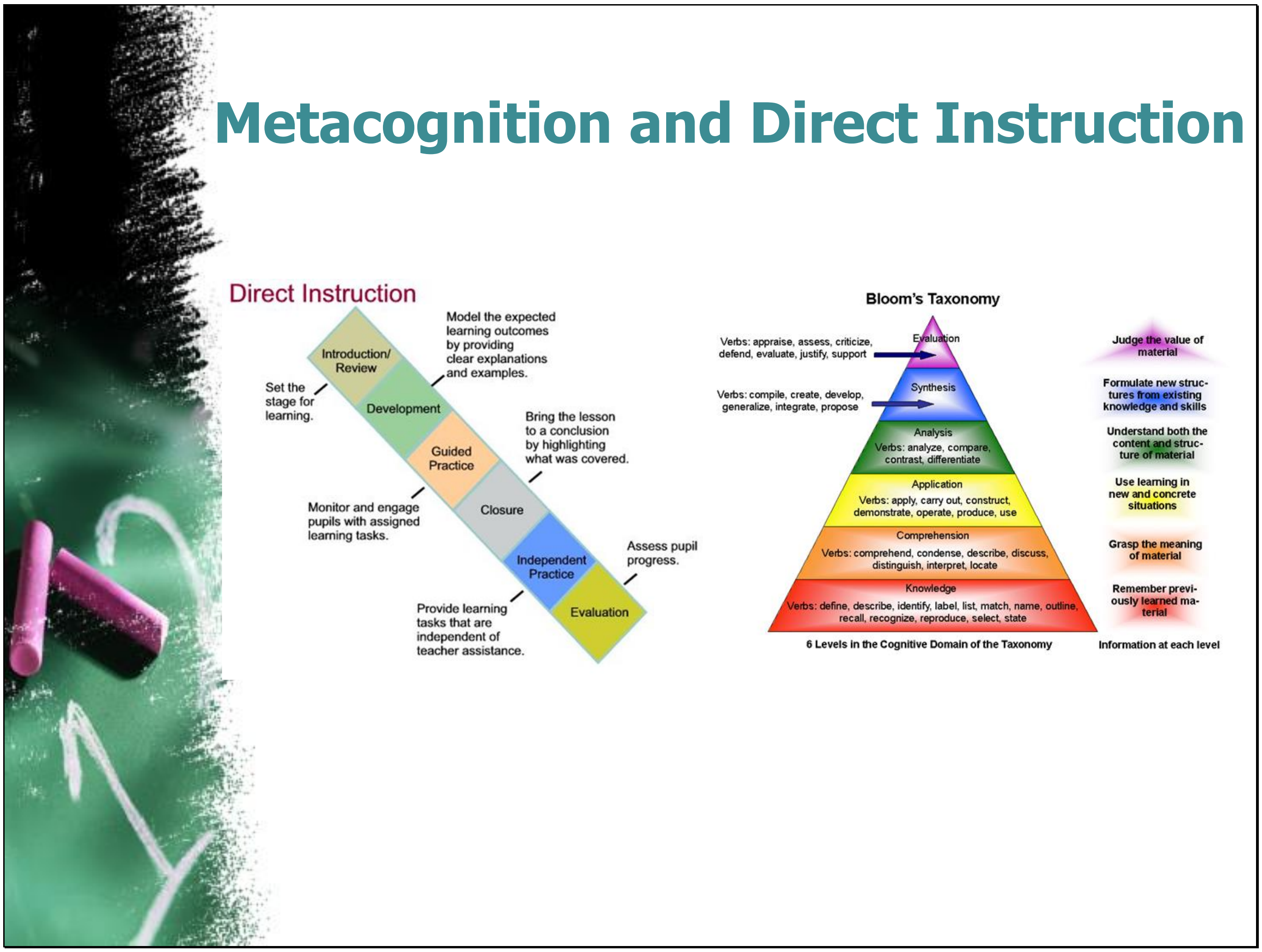

The clear organized structure of metacognition and direct instruction is also supported by Blooms taxonomy, old and new version, in that knowledge or strategy gained can be applied and used in new and unfamiliar scenarios within the math classroom (Forehand, 2011). In addition to this, in regards to strategies creating success, Blooms taxonomy clearly indicates that metacognition and metacognitive knowledge is tantamount in attaining educator and student goals. The revisions to Blooms taxonomy lays out a formula consistent with DI practices for cognition and achievement success by highlighting the importance of factual knowledge, conceptual knowledge, procedural knowledge, and the aforementioned metacognitive knowledge (Krathwohl et al., 2002); this can be seen by examining the similarities between DI and Blooms taxonomy in the figures.

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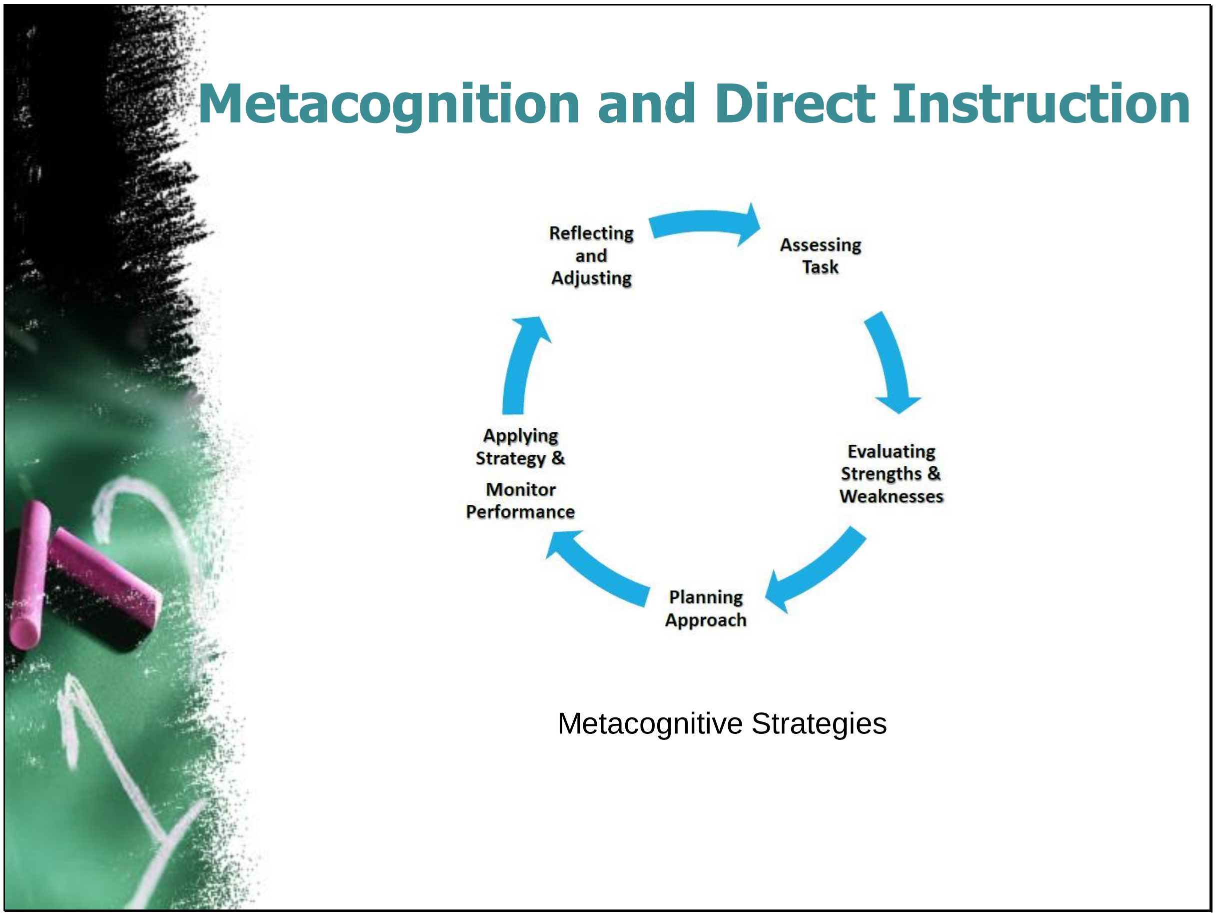

DI's review, development, guided practice, closure, independent practice, and evaluation are similar to Blooms taxonomy structure of knowledge comprehension, application, analysis, synthesis, and evaluation respectively. Using these steps to teach the learner metacognitive strategies will lead to a continual cyclical process (figure 8) of assessing the task, evaluating strengths and weaknesses, planning an approach, applying strategy and monitor performance, and reflect and adjust to the topic studied as needed (Ambrose, 2010; Franco, n.d.).

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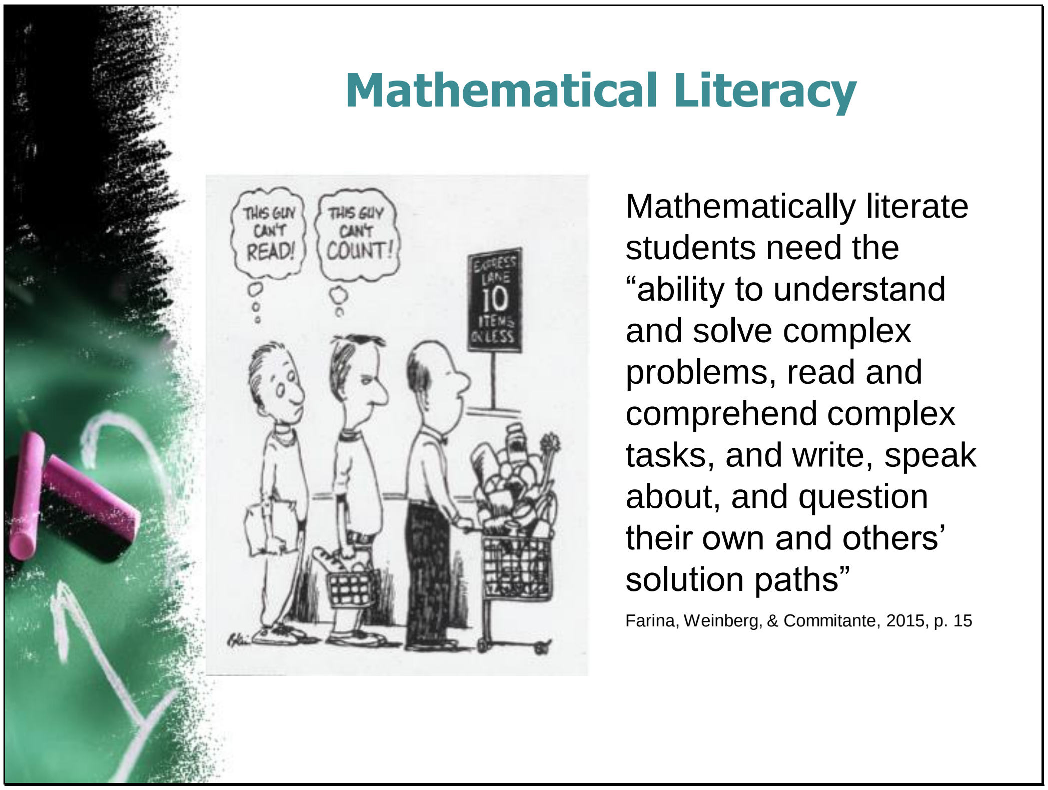

Math literacy is the idea that not only do students know the language and vocabulary of math but also have the ability to analyze, reason, apply, and solve problems in familiar and unfamiliar contexts. According to the disciplinary literacy model (Farina, Weinberg, & Commitante, 2015) every subject has its' own set of language, terminology, and procedures that students need to know. For example to be mathematically literate students need the "ability to understand and solve complex problems, read and comprehend complex tasks, and write, speak about, and question their own and others' solution paths" (Farina, Weinberg, & Commitante, 2015, p. 15). The subject of math is its own language with numerical and non-numerical symbols that the learner needs to decipher before meaning can be made from a problem, and the problem solved. Math textbooks also have diagrams and side bars that may be related to the problem at hand so students need to be well versed mathematically.

To ensure this happens the math literacy metacognitive processes required to problem solve need to be explicitly taught to students for the best chance of success (Farina, Weinberg, & Commitante, 2015). According to Farina et al. (2015), these metacognitive strategies include think alouds, visualization, using guiding questions, writing about mathematical questions and reflections, directly discussing and unpacking the language used in problems, defining function words such as “the” and “a”, defining the vocabulary such as prime numbers or mean, using word walls, and discussions regarding problems to allow for immediate feedback. Farina et al. (2015) also promote the use of funneling, use of questions to arrive at a pre-established procedure, or focusing, listening to what students say to indicate their thoughts and how they communicate with others, to promote deeper mathematical learning. By directly teaching these metacognitive techniques, it is thought that the educator will enable the learner to be metacognitively and mathematically successful, and mathematically literate.

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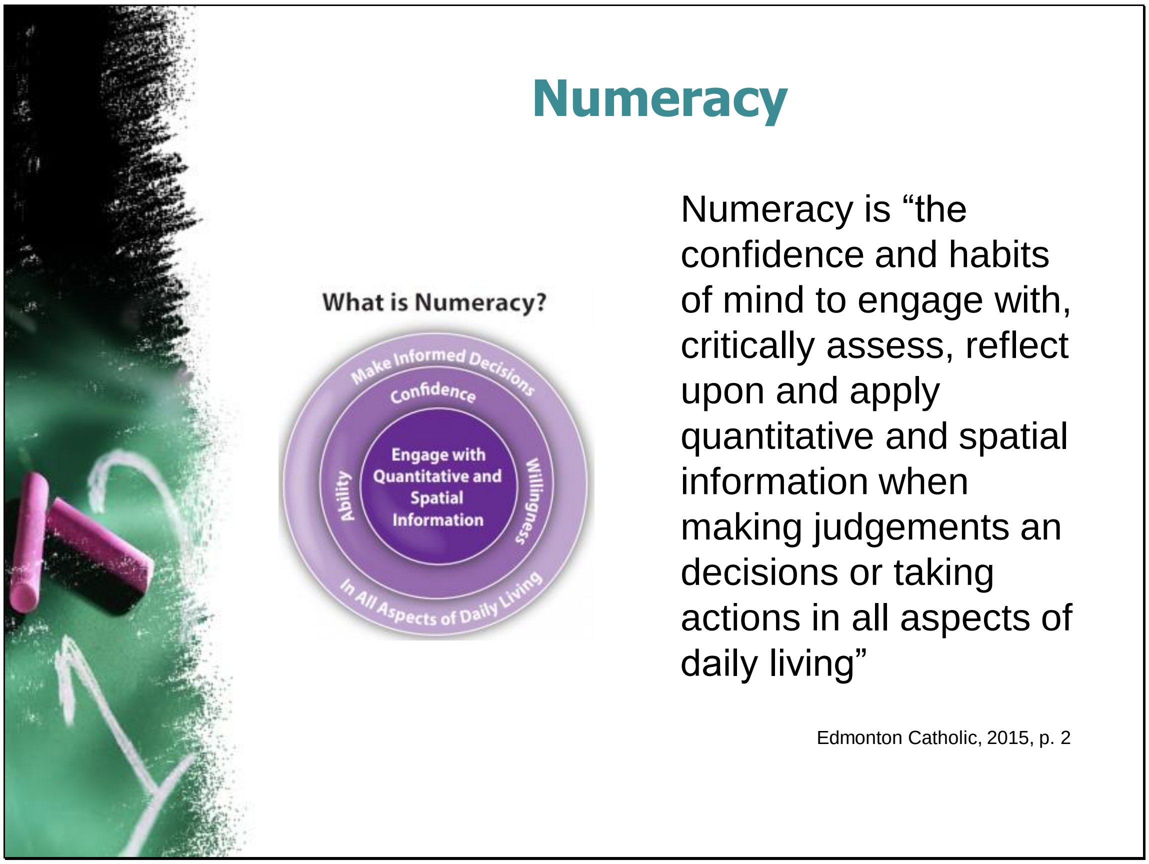

Numeracy is the ability to reason critically about quantitative data (Gittens, 2015) and will help students be successful in and out of the classroom environment. Numeracy is also "the confidence and habits of mind to engage with, critically assess, reflect upon and apply quantitative and spatial information when making judgements an decisions or taking actions in all aspects of daily living" (Edmonton Catholic, 2015, p. 2). Edmonton Catholic Schools District (ECSD) believes it is important to have a good sense of numeracy (Edmonton Catholic, 2015, p. 2), as is indicated by the allotment of significant funds towards mathematical numeracy in the form of teacher professional development (PD), development of math and numeracy community at various levels of education, out of district presenters, as well as a plethora of other forms of numeracy development. To this end ECSD has also promoted numeracy to its educators and students, with the goal of raising student numeracy awareness, by sending out yearly emails for what is called numeracy week, on topics such as symmetry, composing, decomposing, transforming shapes, locating, mapping, orienteering, coding, and perspective taking. There is also π (Pi) day on March 14th detailing how π came about and how it is used. This focus on numeracy comes directly from the ministerial order (Government of Alberta, p. 3, 2013) to ensure that the learner is making use of the metacognitive strategies mentioned previously to maximize numeracy education to help the learner be better equipped to solve mathematical problems.

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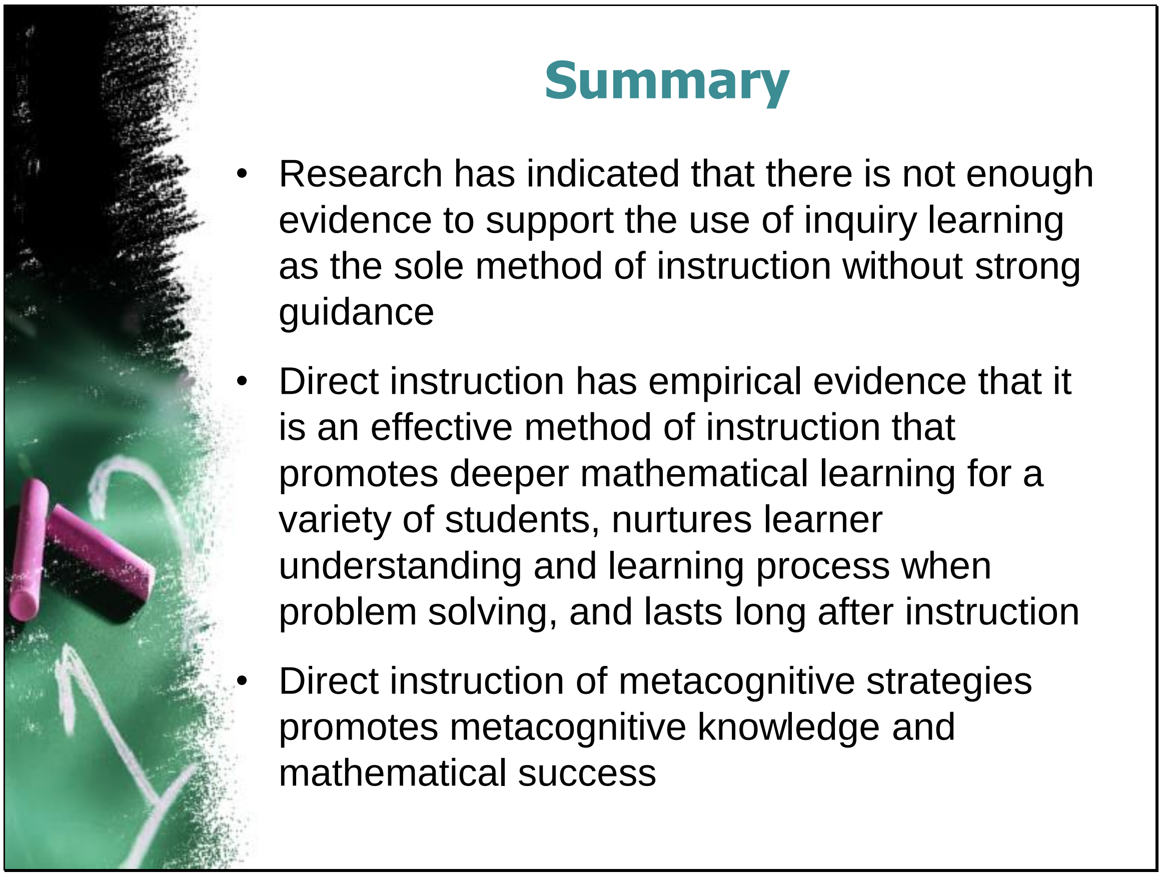
Summary
• Research has indicated that there is not enough evidence to support the use of inquiry learning as the sole method of instruction without strong guidance
• Direct instruction has empirical evidence that it is an effective method of instruction that promotes deeper mathematical learning for a variety of students, nurtures learner understanding and learning process when problem solving, and lasts long after instruction
• Direct instruction of metacognitive strategies promotes metacognitive knowledge and mathematical success

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